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EDITORIAL

The President Professor Cristina Leonelli has kindly invited Antonio Diaferia, Managing Director of EMitech, srl in Italy, to introduce their MISYA system, which was originally applied in the disinfestation of pest control but latterly has been applied to sterilization and drying processes.

I am also delighted to welcome Dr Yuriy Zadyraka of Advanced Microwave Technologies Ltd based in Scotland who describes their efforts to introducing novel systems for heating liquids on san industrial scale using microwave energy.

The Afterthought piece concentrates on RF plasmas.

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MISYA FOR AGROFOOD: MICROWAVE PROCESS AND DEVICE FOR FOOD SAFETY

by **Antonio Diaferia**
Managing Director of EMitech s.r.l.

EMitech srl (Electro Magnetic innovative technologies) is an Italian company with over twenty years experience in the design and implementation of electromagnetic shielding facilities for military and civil applications. Today, thanks to a fruitful applied research on reverberation chamber techniques conducted with multidisciplinary teams, and in collaboration with Italian Universities and Research Centers, it is a leading company in the realization of microwave systems called MISYA (Microwave System Applications).

EMitech's first achievement and main product line is "MISYA for Art", a system using microwaves for carrying out pest control treatment of artistic objects made of wood, paper and cloth, which is very advantageous in terms of effectiveness, efficiency and safety. This successful application of MISYA, in the field of art conservation and restoration, led EMitech's research activities to further developments in those sectors where effective alternatives in the use of toxic and polluting methods are urgently needed. Today MISYA represents a new and valid goal for carrying out disinfestations, sterilization and drying processes in other fields like packaging and agro-food.

Wood packaging materials, particularly pallets which are in use in most of the international and intercontinental deliveries, could act as a pathway for the introduction and spread of pests, representing a threat to living trees. Currently the international standard FAO-ISPM No. 15, which describes the officially approved phytosanitary measures for pest control in wood packaging materials, is being reviewed. In the spring 2013 it will include the microwave pest-control method (Dielectric Heating – "DH"), proposed and submitted by EMitech to the FAO Authorities[1].

Microwaves for Food Safety

The microwave system and process "MISYA for Agrofood", patented by EMitech srl, is an innovative pest control method for legumes, cereals (rice included) and dry fruits which meets all conditions of efficacy, safety, and environmental sustainability. Over the last few years, attention towards food safety has significantly increased and at the same time

[1] www.ippc.int

there has been the introduction of increasingly stringent regulations aimed at reducing the risk of chemical, biological and microbiological contamination of food.

The need to enhance food shelf-life is parallel to the increasing demand for effective prevention methods and phytosanitary means of defence against pests infestations with respect for the environment.

EMitech's study derives from the awareness that foodstuffs of plant origin are subject to the attack of pests, especially in the post-harvest and storage phases. Post harvest Losses (PHL) due to biological infestations can be quantitative and qualitative. Quantitative losses, provoked by crops weight reduction, are generally estimated to be around 10-20 % and FAO estimates even 45% losses in some regions like for example in sub-saharian Africa. Qualitative losses are to be intended in terms of decrease of seed germinability and of nutritional values due to organoleptic changes.

The application of this microwave technology, which enables to treat food in the post-harvest phase, is completely chemical-free and therefore it also meets the requirements of organic farming techniques. It is based on the observation that pests do not survive at a given temperature called "lethal temperature (LT)". Thanks to microwave heat effects, deriving from the interaction between electromagnetic fields and polar molecules, MISYA systems provoke lethality of pests by overheating, that is once their temperature achieves the LT values ranging from 55 to 60°C.

Experimental background

EMitech has been engaged, for many years, with academic partners and institutional laboratories belonging to the Italian CRA (Agricultural Research Council) and CNR (National Research Council). The microwave method for biological disinfestations was also the subject of an important research program fostered and financed by the Italian Ministry of Agricultural, Food and Forestry Policies, which has led to the realization of an industrial device for continuous disinfestations treatments of seeds like legumes and cereals.
Experimental tests were performed mainly on artificially infested samples of chickpeas and beans and naturally infested samples of rice and wheat.

During all tests, lethal temperature for different life stages of pests was achieved: pests' mortality rate has been higher than 98%.

Figure 1. *Legumes coming out from the microwave treatment system. Measurement of output temperatures by means of a thermocamera.*

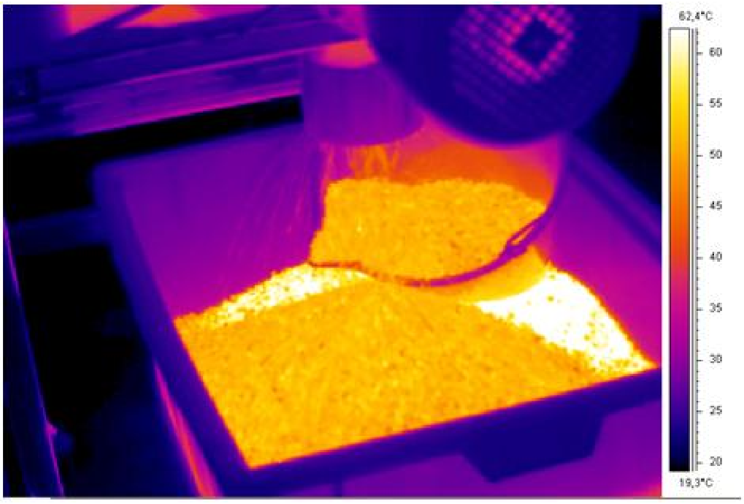

Figure 2. *Thermal image of legumes after the microwave treatment showing the heating uniformity of the product mass under treatment.*

After microwave treatments, physical analyses were carried out to verify possible quality modifications in each seed sample. The whole product mass and the control samples of rice were analyzed taking into account specific physical aspects of grains, mass increment after cooking, volume increase after cooking, alkali test, crystalline grain and aroma. For evaluating the quality preservation in wheat aspects like humidity, colour, nitrogen substance, gelatinization time, sensory properties etc. were analyzed. No significant differences were found in chemical and physical analyses carried out on treated legumes and cereals samples.

Tests have also shown that no remarkable differences were found in germination characteristics between the control sample and samples treated with microwaves.

Microwave device

The industrial outcome of the research work, described above, is “MISYA for Agrofood”: a novel technological solution for the disinfestations of dry fruits and seeds (legumes, rice and other cereals). It is a microwave system for continuous disinfestation consisting of a shielded and reverberating cavity, where the product to be treated moves through a duct. Microwaves are generated outside the cavity by longitudinally placed generators and ensure the heating of food, while it is conveyed from the input to the output, by the mechanism of dielectric loss.

The reverberation of the electromagnetic waves within the cavity, is generated by the rotation of the conveyor device that allows the uniform heating of the mass and consequently ensures that the entire product mass is disinfested.

The loading unit consists of a hopper for the input of the product to be treated, a shielded injection of air at high pressure and an electromechanical dispenser.

Microwaves heat the product so that temperatures achieve the pre-established LT values: studies and tests carried out on various types of foodstuffs of plant origin have shown that most biological forms infesting these products, when exposed to microwaves reverberation into the equipment described above, do not survive to temperatures higher than 55°C. As a matter of fact electromagnetic energy makes rise the body temperature of pests until and above their LT.

Figure 3. *MISYA for Agrofood: mod. AH-36-T (2009)*

The temperature can be adjusted during the treatment by controlling the speed of the conveyor, thus increasing or decreasing the product's exposure time to microwaves (and consequently varying the amount of energy transformed into heat). All parameters are constantly monitored and managed by a suitable control and management system.

Conclusions

The use of MISYA for Agrofood, based on the microwave reverberation chamber technology, allows to disinfest food of plant origin through a physical method not affecting the characteristics of products and by respecting organic farming techniques.
This method is completely effective and safe for operators, the environment and food consumers because it does not leave noxious and dangerous residues in the treated products.

Aware that food safety, being a key strategy for all the international organisations committed to ensuring a high level of public health and well-being as well as good nutrition and food security for all, EMitech has drawn the attention of these Organizations on the availability of this technology, the innovation it represents and its potential with all ecological and socioeconomic implications. Therefore EMitech recently presented "MISYA for Agrofood" to IFAD (International Fund for Agricultural Development) and has also been invited by FAO, whose officials have recognized that its implementation in the field of biological disinfestations could enhance food safety, food security and eco-sustainability in developing countries.

Antonio Diaferia, is a young Engineer leading EMitech's R&D group engaged in the study and industrialization of microwave innovative applications in Italy.

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MICROWAVE HEATING OF LIQUIDS ON AN INDUSTRIAL SCALE

by **Dr Yuriy Zadyraka**
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Advanced Microwave Technologies Ltd has developed a unique method of delivering microwave energy into flowing liquids, suspensions and semi-solids on a continuous basis, and an industrial scale.

The principles and equations that govern the interaction of electromagnetic energy (including microwave energy) with materials have been known for over 50 years. In the earlier 1950's they were used to develop equipment and methods for processing food at the industrial level as well as within our homes (microwave oven in our kitchens).

However it became evident that this microwave-based method produces uneven heating in the product due to the non-homogeneous electromagnetic fields inside the treatment chambers. This, together with the fact that the ultimate use of the treatment chambers restricted cooking to the batch process, has not only slowed down the use of the microwave equipment in food industry for cooking solids, but has also inhibited the development of commercially viable equipment for processing liquids on an industrial scale.

Although promising results have been obtained for the microwave treatment of liquids at a laboratory scale for applications such as microwave assisted chemistry and the microbial eradication on liquid media, it has proven difficult to develop this to an industrial scale. It appeared to be more difficult to treat liquids using microwave compare with microwave treatment of solids.
The reasons for this have apparently been overlooked by the designers and end users of microwave equipment for the treatment of liquids. Very often the microwave treatment of liquids is narrowed down to treatment of water and water contained mixtures, and so I will discuss this further using water as an example.

Microwave absorption of water depends on the angle between the electrical component (vector E) of the fallen/incident microwave signal and the surface of the water. It is known that the highest level of microwave absorption is achieved when the angle between vector E and the surface of water is close to 900. This fact need to be taken into account when designing microwave liquid treatment systems.
The next important factor is the intensity (I) of the microwave irradiation. Everything which is below I = 5W/cm2 is a low-intensity microwave irradiation. At this level of intensity when it is applied to microwave liquid treatment it means that the microwave irradiation could not change the electrical properties of the liquid. The propagation of low-intensity microwave through the liquids is described by the Bouguer law which is well known in linear electrodynamics. Also in this case the absorption properties of the water do not depend on the intensity of the microwave. For the low-intensity microwaves, the absorption and reflection properties of liquids are well established. The absorption coefficient for water is α = 2 cm-1and accordingly the depth d at which the intensity decreases by a factor of e is 5 mm. In the case of high conductivity of water (saline water) when the conductivity of water reaches 2000µS/cm, the absorption coefficient increases to 4 cm-1 and the absorption depth is down to 2.5 mm.

The situation changes dramatically when the intensity of microwave is so high that it is able to change the electrical properties of the liquid. In this case the microwave penetration into the liquid cannot be described by linear electrodynamics.There are different ways of changing one regime to another, to go from linear to non-linear electrodynamics. The obvious one is to increase the output power of the source of microwave irradiation. This could be technically challenging and commercially costly option.

The other way of changing the regime is by varying the retention time of the liquid within the microwave system. During the short retention time (t <1sec), the propagation of microwaves through the liquid is consistent with that described by linear electrodynamics. When the retention time is long enough (t >10sec) the character of microwave penetration into the liquid changes radically. During this retention times microwave irradiation substantially changing the dielectric properties of the water. Initially microwave energy absorbed in a narrow surface layer with the thickness determined by the Bouguer law and heats this layer. The absorption coefficient for tap water decreases with the rise of water temperature. Hence, the heating of the surface layer is accompanied by the increase in its transparency, and the microwave irradiation penetrates deeper into the water. As a result, the penetration depth progressively increases as successive water layers are heated one after another. So called “the transparency wave” is created which could be characterised by its own propagation velocity Vz. By comparison the time of the temperature propagation created by thermal heating (heat conduction) is substantially longer than the retention time of the liquid inside the microwave treatment system. Therefore, the time evolution of the temperature propagation through the water reflects the time evolution of the microwave energy penetration through the water. The effect of microwave penetration into the water depths substantially deeper than the absorption depth d, corresponding to the regime of linear electrodynamics, can be classified as the effect of the induced transparency of the water under the action of high-intensity microwave irradiation.

Based on these findings AMT took the second approach and designed their system around the effect of the induced transparency of water under the action of high intensity microwave irradiation. The dimensions of the microwave chamber have been chosen to achieve the highest level of microwave absorption due to the right angle between electrical component of generated electromagnetic wave and the surface of the liquid passing through the chamber.

To create inside the chamber the regime of induced transparency designers have been using industrial off-shelf magnetrons which generated high-intensity (I = 14 W/cm2) quasi-continuous microwave irradiation with λ = 12.2 cm. To guarantee that the retention time of the liquid inside the treatment chamber is long enough (t >10 sec) and that at the same time the system is capable of treating liquids on an industrial scale, AMT designers came up with the idea to use a number of treatment chambers in a way that the treated liquid is passing through the chambers, one after another. Varying the flow of the liquid and/or the number of the treatment chambers the commercially required volumes of treated liquid and its final temperature could be achieved.

This revolutionary approach has been termed Microwave Volumetric Heating. Early adopters of this technology have come from within the food and drink industry and its application for other high value manufacturing processes is currently being explored.

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NEWS FROM NPL

It is also proposed to establish an Advanced Metrology Laboratory at NPL (National Physical Laboratory in UK) to enhance the UK's capabilities in quantum technologies, nanotechnologies and innovative materials, building on NPL's world-leading expertise. It will also facilitate interaction between NPL and industry, universities and other collaborators to help support UK growth through cutting-edge technological development and application.

It has recently been announced that NPL will be part of the Graphene Flagship consortium that has been allocated some ½ billion euros by the EC to towards R&D on graphene, a single atom layer conducting form of carbon composite (see the Afterthought piece in March's issue of this Newsletter).

The applications envisaged are in batteries, electronics, sensors or computing.

EVENTS

IMPI Congress 2013

The 47th IMPMI Symposium will be held at Providence Biltmore Hotel, Providence, Rhode Island, USA, 25-27 June 2013
For more information contact Executive Director Molly Poisant
Tel: +1 804 559 6667
molly.poisant@impi.org or browse at www.impi.org

Microwave and Flow Chemistry Conference 2013

Enabling Technologies for Discovery, Process and manufacturing
20-23 July 2013
Silverado Resort and Spa
Napa Valley California
United States
For more information contact Emma Scarlett at www.zingconferences.com or visit:
www.zingconferences.com/index.cfm?page=conference&intConferenceID=112

PIERS 2013

Progress in Electromagnetics Research Symposium (PIERS)
Stockholm, Sweden, 12-15 August, 2013
http://www.piers.org/piers2013Stockholm/
For more information contact The Electromagnetics Academy
Email: tpc@piers.org
http://emacademy.org/
http://piers.org/

14th International AMPERE Conference 2013

The 14th International AMPERE conference on Microwave and High Frequency Heating will be staged at National Centre for Industrial Microwave Processing which is based at Nottingham University, UK. The conference will be held during 16-19 September 2013. 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 www.ampereeurope.org

EHE2013

The next International Conference on Electromagnetic Fields, Health and Environment, will be held in Porto, Portugal, from 19th to 21st September, 2013.
For more information browse at: http://www.apdee.org/index.php?pageid=1578

RUSTUM ROY MEMORIAL SYMPOSIUM

October 27-31, 2013, Montreal, Quebec, Canada.
The "Rustum Roy Memorial Symposium: Processing and Performance of

Materialsusing Microwaves, Electric and Magnetic Fields, Ultrasound, Lasers, and Mechanical Work" at **Materials Science & Technology Conference and Exhibition (**MS&T`13).
Organisers: Morsi Mahmoud and Guido Link at Karlsruhe Institute of Technology, Dinesh Agrawal Penn State University, Motoyasau Sato, Chubu University, Japan and Rishi Raj, University of Colorado at Boulder.
This is a Special topic in the list of topics for presentation at the Conference. Visit http://www.matscitech.org for details

AN AFTERTHOUGHT : RF PLASMAS

Much has been written about plasmas, their origin and classification. Ignoring what type of plasmas exists in the universe, artificially produced plasmas on earth can be very hot fully ionised plasmas where all the electrons are stripped from their atoms, such as those as one encounters in fusion research as well as cold dense plasmas which are partially or weakly ionised and of lower temperature which find uses in industry and other sectors. When introducing a review of industrial applications of RF and Microwaves in various formats of my short courses, I always include a few slides on plasma processing for microelectronics. In this application very large scale integrated circuits are produced using plasma based technologies, such as plasma etching or plasma-enhanced chemical vapour deposition. The frequencies for these processes lie in the region 1-200 MHz and this frequency regime is very interesting in that the electrons are able to respond to the instantaneous electric fields established within the processing region. The usual way to experimentally obtain a plasma is through capacitive coupling using two parallel plates immersed in a glass vessel containing the gas to be ionised or indeed the plates could be external to the vessel.

Alternatively, a coil could also be wrapped around a cylindrical glass vessel (not extending the whole of the length of the vessel) thus producing an inductively coupled system for exciting the gas. In this case by coupling low power to the coil, a low temperature plasma is produced which occupies the whole of the volume of the vessel. However, by increasing the current flowing through the coil, essentially increasing the electric field established across the ionised gas, suddenly a level of current is reached whereby a transition occurs to an intense luminous region embracing only the region of the coil called a “ring discharge”. What causes this transition and which processes dominate? Could this be the source for some industrial chemical processing in the future? How about rocket propulsion using electrostatic ion thrusters?

The theory behind the formation of such plasmas is eloquently described in a recent book by Chabert and Braithwaite (2011) encompassing the microscopic, macroscopic as well the electrodynamic perspectives. Radio frequency sheaths are analysed in detail and modelled effectively. Single and multi-frequency capacitatively coupled systems follow leading to inductively coupled systems. The book ends with a section on real plasmas in the sense that the idealised treatises have to be modified to account for wall effects and the existence of other species within the reaction vessel.

Reference

P. Chabert and N. Braithwaite, Physics of Radio Frequency Plasmas, CUP, 2011

AC Metaxas.
Editor

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