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EDITORIAL

I am delighted that Professor Juming Tang of the Washington State University has accepted my invitation to develop his ideas concerning the microwave assisted sterilisation (MATS) project that he conceived right down to the ensuing FDA acceptance of this process some seventeen years ago.

I am also very pleased to have David McLean describe some of his operations on microwave energy for industry at Advance Microwave Technologies. This is the company he set up and which emerged out of the work that was carried out on microwave heating applications at Wollongong University in the late 1980’s and where David currently is a Fellow.

The Afterthought piece in this issue concentrates on the solar power space system for power generation which has its origins in the work in the 1960’s carried out by William Brown’s at Raytheon and Peter Glaser at Arthur D Little. Fifty years on and this idea is now seriously being funded and experimented with in Japan.

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MATS DEVELOPMENTS IN THE USA

by **Juming Tang,** PhD., Professor
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Two months ago, Dr. Metaxas asked me to write a short article for Ampere Newsletters about the development of microwave assisted sterilization (MATS) in my research laboratory and the current status of commercialization. Instead of reporting only the technical aspects of the progress, I decided to write with a slight personalized touch to acknowledge some wonderful individuals who helped me through the past 17 years journey, from conceiving the concept to final FDA acceptances of the MATS processes.

Brief background

Conventional canning operations for production of pre-packaged low-acid (pH>4.6) shelf-stable foods use pressurized steam or high temperature water to bring the interior of the pre-packaged foods to about temperature 120 °C or above. The goal is to inactivate Clostridium botulinum spores type A and B that could otherwise germinate and produce deadly toxin in sealed containers. A commercial process typically takes 30 to 120 minutes, depending on the size of the containers. The lengthy heating time causes thermal degradation of the final products. Over the past forty years, major US food companies and US Army have shown strong interest in using microwave energy to shorten the heating time and improve product quality. US Army Natick Soldier Center led the development efforts by designing a pressurized 10 kW 2450 MHz pilot-scale unit (Kenyon et al., 1970). But the project could not overcome several key technical hurdles (DeCareau, 1985). Many large food companies in the USA started their own internal R&D activities in the 1980s or attempted to adopt 2450 MHz systems developed in Europe in the early 1990s. Those efforts did not result in any success. Yet, the interest in microwave sterilization remained strong. For example, in a survey conducted by Food Engineering Magazine, executives of food companies predicted microwave sterilization to be a major food manufacturing trend in the twenty first century (Morris, 1996). Two unique challenges faced by large US companies for adopting a new sterilization technology for low acid shelf-stable foods are: 1) new commercial systems should deliver adequate throughputs required for the US market, e.g., between 50 and 250 meals per minute; 2) commercial production processes must receive acceptance from US Food and Drug Administration (FDA) and blessing from USDA Food Safety Inspection Services (USDA FSIS), for which solid experimental data and scientific information are required to provide convincing proof that the processes are reliable in producing safe products.

How I got started

When I joined Washington State University (WSU) as a faculty member in 1995, I was asked by department chair Dr. Ralph Cavalieri to initiate a new research program on novel food processing technologies. After searching the literature I decided to work on microwave heating using 915 MHz systems. I first started a small project on microwave drying. At the1996 IMPI Annual Meeting in Boston, I met Robert V. Decareau. My interest in microwave heating had been inspired by his book "Microwaves in the Food Processing Industry" published in 1985. Bob encouraged me to work on microwave sterilization, and introduced me to US Army Natick Soldier Center scientists Drs. Irvin Taub and Tom Yang.

At that time, Dr. Taub had completed a 10 year research project on chemical markers M-1, 2 and 3 that could be potentially used as integrated indicators of heating patterns in microwave heating. Dr. Yang and Dr. Taub were attempting to resurrect the microwave sterilization program at the US Army Natick Soldier Center. After listening to my thought of using 915 single mode design for microwave sterilization system, Dr. Taub decided to support me with small grants ($20,000/year) and provided a summer internship for my PhD. student Ming Lau to learn chemical marker methods in his laboratory at the US Army Natick Center. We built a small 5 kW 915 MHz unit in 1997. After seeing our first microwave sterilized product, macaroni and cheese, Evan Turek a research fellow and visionary engineer with Kraft Foods convinced his company to jointly (with Natick Soldier Center) support our earlier development of 915 MHz MATS technology.

A journey to receiving regulatory acceptance

Between 1999 and 2001 the US Department of Defense Dual Use Scientific and Technology (DoD DUST) program solicited proposals for projects on novel food processing technologies for military rations. A requirement for successful proposals was 100% cost share by US food companies.

In response to this once in a life time opportunity, Washington State University Microwave Consortium was formed in 2000 with the ultimate goal to translate the original MATS design concept into commercial reality. Six companies, i.e., Kraft Foods, Hormel Foods, Truitt Brothers, Rexam Containers, Ferrite Component, and Graphic Packaging, participated as the initial consortium members. Several other companies, e.g., Mars Foods, Ocean Beauty Seafoods joined the consortium later. We successfully secured a two year grant from DoD DUST program in 2001. US Army Natick Soldier Center and consortium industrial members continued to provide support when the two year DUST program ended in 2004.

Research and development activities in my laboratory, supported by the consortium, focused on achieving five major objectives: 1) developing a scalable 915 MHz microwave sterilization system that can provide predictable and stable heating patterns in packaged foods, thus making it possible to receive FDA acceptance; 2) developing effective means to assess heating patterns; 3) developing computer simulation models to support system and process design; 4) developing protocols for FDA and USDA FSIS acceptance; 5) support technical transfer for commercialization. For the system design, we combined 915 MHz microwave applicators with thin-layer circulation water to process packaged foods in four interconnected pressurized chambers. Proper phase control between two opposing entry ports for each chamber enabled control of heating patterns in food packages. We used chemical marker M-2 to visualize heating pattern and locate the cold spot in the food package. We then used mobile temperature sensors to measure product temperature at the cold spot for process development.

Fig. 1. *Engineers and students assembling the 2nd generation pilot-scale 915 MHz MATS system in 2002. It had two heating cavities, and could process four food packages in a batch mode.*

The system's thermal processes shortened the time needed to ensure food safety at 121 ^{o}C to just 5-8 minutes for foods in single-meal packages. The shorter processing times sharply reduce thermal degradation of food quality and nutrition and make possible fully automated industrial operations. We used C. sporogenes PA 3769 spores as the surrogate for C. botulinum type A and B spores for process validations.

Fig. 2. WSU engineers (Zhongwei Tang, Frank Younce and Frank Younce) with the third generation 915 MHz pilot scale MATS system (24 m in total length). It consists of four single-mode cavities and pressurized chamber to allow processing of 50 meals in a semi-batch mode.

With technical support from Seafood Products Association, Washington State University received FDA acceptance for MATS processing of a homogeneous food (mashed potato in trays) in October 2009. One year later on December 15, 2010, we received notification that FDA accepted application for MATS processing of a nonhomogeneous product (salmon fillets in sauce packaged in pouches).

In March 2012, we received non-objection from USDA FSIS, using new data for MATS processing of another non-homogeneous food: chicken and dumpling packaged in pouches. Clearance of regulatory hurdles paves the path for commercialization of MATS in USA markets (Brody, 2012).

Fig. 3. WSU team members preparing samples for microbial validation tests in MATS system for the first FDA filing.

Fig. 4. Tang and the regulatory sub-team of Microwave Consortium met with FDA scientists in connection with the first FDA filing in 2008.

Fig. 5. WSU Consortium received 2010 R&D Award from Institute of Food Technologists in 2010 for first FDA acceptance of MATS process. From left, IFT President, Evan Turek (Kraft), Kenny Lum (Seafood Products Association), Douglas Hahn (Homel), Pat Dunne (US Army Natick Soldier Center), Juming Tang (WSU).

Fig. 6. Consortium industrial members and WSU team comparing quality of a product processed with MATS process (left in the screen) with conventionally processed counterpart (right, note the severe color degradation)

Commercialization

In 2010, Washington State University licensed the right of commercialization of MATS to Food Chain Safety, a start-up company in the Seattle area, and formed Consortium II in June 2010 to support technology transfer. The new consortium was expanded to include more of the world's top food companies (e.g., Nestle, Pepsi-Cola) and two military ration producers (Wornick Foods, OH and Ameriqual, IN). Food Chain Safety delivered the first industrial pilot-scale system to Ameriqual in September 2012, has scheduled to deliver another one to Wornick Food in December 2012, while designing an industrial system that can process up to 150 meals per minute for delivery to Ameriqual in 2013.

It has been truly a multi-disciplinary 17 year endeavor involving over one hundred research scientists, engineers, technicians, students and staff from Washington State University, US Army Natick Soldier Center, Seafood Products Association, National Products Association, industrial consortium members, and FDA and USDA FSIS. Direct participation and support of industrial members and close consultation with regulatory agencies allowed us to stay on course. But the journey is not over. New technical and scientific challenges will surface as we transit to full-scale commercialization.

References:

Brody, A.L. 2012. *The coming wave of microwave sterilization and pasteurization*, Food Technology Magazine, 66, (3):78-80.

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Kenyon, E.M., Westcott, D.E., LaCasse, P., and Gould, J. 1970. *A system for the continuous processing of food pouches using microwave energy*. J. Food Science 36(2), 289-293.

Morris, C.E. 1996. *Manufacturing forecast accelerating changes.* Food Engineering Magazine, March Issue, 73-77.

MICROWAVE APPLICATIONS AT ADVANCED MICROWAVE TECHNOLOGIES

By **David McLean**
Advanced Microwave Technologies Pty Ltd
Australia

One of the most exciting days of my life was the 25th of July 1988, I had spent 9 months in anticipation of my first child and approximately 3 months waiting to start a position as a research Engineer with the Microwave Application Research Centre (MARC), part of the commercial arm of the University of Wollongong. Both eagerly awaited events finally become a reality on the same day.

My initial enthusiasm for the new job continued to increase at a steady rate for approximately 10 years. I was completely enthralled by electromagnetic fields and their interaction with materials. I read every book I could get my hands on and was constantly marvelling at the rich and complex nature of microwave heating and the beauty of Maxwell's equations.

All this enthusiasm was aided significantly by our group leader Prof Howard Worner, one of Australia's most prodigious scientists who, at 75 years old when I joined MARC, had the most creative and disciplined mind I had ever come across. His humility and intellect combined to create a dynamic environment in which everybody felt valued and important.

This nirvana was soon to be temporally shattered when given the chance to implement our first industrial system into the local steel producer. Our microwave paint viscosity controller worked perfectly in the lab and installation into the paint line was scheduled during a routine maintenance shut down. The tight time table and pressure to have the system work in a dirty and hazardous industrial environment was something I had not faced before and circumstances saw us working through the night on many occasions. Eventually we had to remove the system and depart with our tail between our legs.

I learnt a lot from the many mistakes made over the years and, providentially for me I was working for the University when these events happened. As the years rolled by we were engaged in a broad spectrum of projects ranging from drying to high temperature materials processing, with various specialists being brought in at the appropriate times. Fortunately for me there was a need for a microwave engineer in almost every project, so while others come and went, I remained and gradually moved into a more critical role.

After about 15 years working for the Wollongong University's commercial arm (ITC) and with a great deal of support and help from my former employer, I set up my own company called Advanced Microwave Technologies Pty Ltd (AMT).

Over the years AMT has found a niche in helping companies scale their small laboratory processes up into full scale industrial processes. Typically, the issues that proved the most troublesome at the laboratory scale, such as even heating, energy efficiency and control, seemed to transform into other challenges once a process was scaled up. Four important problems that we come across regularly are listed below;

1. Materials handling – particularly when dealing with bulk solids. How do you get a material in one form into the microwave cavity, have it heat rapidly , change form and then get is back out again? This is a constant challenge if a chemical reaction or density transformation has been initiated by the microwave process.

2. Plasma control – in many high power applications involving elevated temperatures, plasma control is a serious consideration. The many advantages of compressing the microwave power density into a very compact applicator can significantly increase the risk of plasma formation and the mitigation of this risk requires specific attention as it will depend upon the process variables gases evolved, chemical reactions taking place and the form of material being heated.

3. Process Equipment Materials selection. – The decoupling of the microwave source and the need for process containment, often requires much consideration. Corrosive gases, hot materials and thermal runaway in various refractories if not given careful attention will mean the process will never be reliable and could become a white elephant.

4. Operators Onside – Most of the process development work that AMT has undertaken involves a new approach to heating that is, as far as the customer is concerned. Ensuring that operators understand that traditional heat transfer mechanisms do not dominate in microwave processes can take both time and patience. Operators can make or break a new process by their understanding or lack of and their subsequent response to an unusual process event. It is essential that the operators not only understand the system but are part of the ongoing improvement process.

My enthusiasm for industrial microwave engineering is still very high and I can't imagine another field exposing me to the variety of interesting people technical disciplines within such a short time, mechanical, electrical, chemical, materials handling technologies, plasma physics, heat transfer and control, to name a few. Microwave Heating is a fascinating field that I would recommend to anyone that enjoys variety and challenge.

EVENTS

HOTPOT: END OF PROJECT CONFERENCE AT TWO CENTRES, FRANCE AND UK
"Food and Poverty"
Tuesday 22nd January 2013
Institu Polytechnique LaSalle Beauvais, France
Guest Speaker: Martin Hirsch, President de L'Agence du Service Civique

and

Wednesday 23rd January 2013
Old Ship Hotel Brighton, UK
Guest Speakers:
Martin Caraher, Professor of Food and Health Policy, City University London, UK
Greg Hooper, Campden and Chorleywood Food Research Association, UK

Jennipher Marshall-Jenkinson, Chairman
Microwave Technology Association UK
For registration visit
m.hoare@brighton.ac.uk

Hotpot is a partnership project between LaSalle and Brighton selected under the European Cross-border Cooperation Programme INTERREG IV A France (Channel) – England and co-funded by the European Development Fund (ERDF)

15th Seminar "Computer Modeling in Microwave Engineering and Applications" Multiphysics Modelling in Microwave Power Engineering
March 4-6 2013
Cetana Amalfi coast Italy

Organised by:
IMMG, CIMS, Dept of Mathematical Sciences, WPI, USA and
Society of Industrial and Applied Mathematics and
Italian Group for Microwave Application to Materials and Processing

For more information contact:
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PIERS 2013
33rd Progress in Electromagnetics Research Symposium (PIERS)
Taipei, Taiwan, March 25-28, 2013
The submission deadline of one-page abstract is October 20, 2012.
On-Line-Submission via web page is strongly recommended.
http://www.piers.org/piers2013Taipei/submit/submit_new.php
http://piers.org

HES-13
First announcement and Call for Papers
HES -13 Heating by Electromagnetic Sources
May 21 - 24, 2013
Padova (Italy)
For more information visit www.hes13.org or e-mail Fabrizio Dughiero or Michele Forzan at hes13@dii.unipd.it

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
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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

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

AN AFTERTHOUGHT: A SOLAR POWER SPACE SYSTEM FOR POWER GENERATION; WOULD IT EVER BE A REALITY?

Although William Brown at Raytheon put forward the idea of Microwave Power Transmission (MPT) around about 1964 with a demonstration of a small helicopter powered by a microwave beam and Dr Peter Glazer of Arthur D Little invented the first Solar Power Satellite (SPS) system in 1968, they both could not have envisaged that it will take almost another 50 years when their two ideas are combined in the Space Solar Power System (SSPS) system. In such a system a plant is placed on a geostationary orbit which collects sunlight from outer space, converts the sunlight into microwave energy and beams it down to earth.

The Japanese Aerospace Exploration Agency (JAXA) is researching such an idea and proposes to build a 1GW power plant on earth using SSPS by 2030. Another idea that is seriously been looked at is to transmit the energy back to earth using lasers-in the final analysis which of the two methods will prove to be more successful is hard to tell at present.

William Brown's (the Father of microwave power transmission as he was known) memorial page and achievements could be browsed on the site http://www.solarsat.org/billbrown_memorial.htm which includes a link to a recent article highlighting the work of JAXA in Japan. Further information regarding JAXA' s attempt of harnessing Space based solar power generation can be found in an interview with JAXA's Jasuyuki Fukumuro in http://www.jaxa.jp/article/interview/vol53/index_e.html

AC Metaxas
Editor

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