SCHEDULE OF EVENTS
54th ANNUAL MICROWAVE POWER SYMPOSIUM
(IMPI 54 VIRTUAL SYMPOSIUM)
June 15-17, 2020
V9

All times shown are Eastern Daylight Savings Time and subject to change

Monday, June 15, 2020

9:00am-9:15am: **Welcome & Introductions**
Graham Brodie, University of Melbourne, Australia
Bob Schiffmann, RF Schiffmann Associates, Inc. USA

9:15am-10:00am: **KEYNOTE ADDRESS**
Why Microwave-heating is More Than *Just* Heating?
B. Reeja Jayan, Carnegie Mellon University, USA
Electromagnetic fields absorbed within a material may not be immediately converted to heat but can instead result in field-driven "non-thermal" effects. In some cases, even new behavior evolves such as ceramics that are ductile and can be drawn into wires that survive high temperatures and other extreme environments that metals cannot. However, the underlying fundamental mechanisms behind these observations remain largely unknown. This talk will describe my lab's ongoing efforts to merge exploratory experiments and computation with data-driven methods to define new theoretical foundations that explain the behavior of groups of atoms under microwave radiation. Our goal is to demonstrate how such non-thermal effects of microwave fields can be used to engineer new materials.

SESSION: INDUSTRIAL PROCESSING I & MODELING
Session Chair: Vadim Yakovlev, Worcester Polytechnic Institute

10:00am-10:30am: **INVITED: Continuous Flow Microwave Processing of Foods and Beverages: From 1 to 100 Liters per Minute and Back in 25 Years**
Josip Simunovic[1] and Michael Druga[2] [1]North Carolina State University, USA
[2] SinnovaTek Inc., USA
Continuous flow microwave processing is an advanced thermal technology used for heating and preserving foods, beverages and biomaterials. Both 2450 MHz and 915 Mhz processing systems are currently in commercial use. Evolution of designs and processing capabilities ranging from benchtop to pilot to commercial production is reviewed and illustrated with representative examples of applications. Most recent developments have been focused on small capacity, flexible and potentially mobile systems.

10:30am-10:50am: **Comparison of Microwave and Conventional Heating for CO_2 Gasification of Different Rank Coals**

Candice Ellison[1,2], Victor Abdelsayed[1,2], Mark Smith[1], and Dushyant Shekhawat[1] [1]National Energy Technology Laboratory, U.S. Department of Energy, USA [2]Leidos Research Support Team, USA

Three different rank coals were gasified under 66.6% CO_2 atmosphere (Ar balance) during microwave irradiation (2.45 GHz) and under conventional heating to a temperature of 700 °C. Yields of syngas (H_2+CO) were greater under microwaves compared to conventional gasification, which is attributed to localized hotspots generated within the coal and causing accelerated conversion to syngas via cracking.

10:50am-11:00am: **BREAK**

11:00am-11:20am: Microwave Sintering of $BaTiO_3$ for Multilayer Ceramic Capacitors

Juan A. Aguilar-Garib, Osvaldo Tijerina-García and Javier Garza-Guajardo, Universidad Autónoma de Nuevo León, Mexico, San Nicolás de los Garza, México

It is proposed in this work that the dielectric of multilayer ceramic capacitors (MLCC's), based on $BaTiO_3$, is suitable to be sintered with microwaves. The tests were conducted at 1050°C and 1150°C for 20 minutes in the case of microwaves and the same results in terms of density were obtained after 120 minutes for conventional sintering. A contribution of this work is that it compares two sintering processes in similar conditions of temperature.

11:20am-11:40am: **Microwave-Assisted Extraction (MAE) of Anthocyanins from Different Genotypes of Purple Fleshed Sweet Potatoes (PFSP)**

T. Bhatia, J. Simunovic, K.P. Sandeep, Department of Food, Bioprocessing and Nutrition Sciences, North Carolina State University, USA

Microwave assisted extraction of anthocyanins, using water as a solvent, was implemented at 2450 MHz and optimized using several purple fleshed sweet potato genotypes as substrates. The optimized material (PFSP) to water ratio (1:1) and time- temperature combination (100 °C for 9 minutes), determined from preliminary experiments, were used to efficiently extract total phenols and anthocyanins from PFSP. This resulted in reduced degradation of anthocyanins and extraction efficiencies ranging from 32.3% to 98.7% for phenols and 29.5% to 67.4% for anthocyanins, depending on the genotype of PFSP.

11:40am-12:00pm: **Simulation of Temperature Fields in Microwave Processing of SiC_f/SiC Composites**

Jon Binner[1], Roger Morell[2], Matthew T. Porter[1], and Vadim V. Yakovlev[3] [1]School of Metallurgy and Materials, University of Birmingham, U.K. [2]National Physical Laboratory, U.K. [3]Department of Mathematical Sciences, Worcester Polytechnic Institute, USA

Recent advancement of microwave-enhanced chemical vapor infiltration technology provides insight on unexplained experimental observations and a lack of reproducibility in production of SiC_f/SiC composites. Computations have revealed multiple resonances in the 2.4-2.5 GHz frequency range so that microwave heating at closed frequencies happens at different rates. Simulated temperature patterns show strong sensitivity on small changes in geometry.

12:00pm-1:00pm: **EXHIBITOR SHOWCASE**

Ferrite Microwave Technologies, Odyssey Technical Solutions, SAIREM

SESSION: MICROWAVE AGRICULTURE & INDUSTRIAL PROCESSING II
Session Chair: Graham Brodie, University of Melbourne

8:00pm-8:20pm: **Microwave Holography for Timber Assessment**

Graham Brodie[1], Berhan Ahmed (Shiday)[1], Deepan Babu Thanigasalam[1], Peter Farrell[1], Allison Kealy[2], and John R.J. French[3] [1]University of Melbourne, Australia [2]RMIT University, Australia [3]University of the Sunshine Coast, Australia

Embedded objects, such as decay fungi, termites or electrical cables, within another medium, such as timber or soil, will perturb propagating electromagnetic fields, creating a diffraction pattern (i.e. a hologram) that can be used to non-destructively detect the presence of these objects. This paper demonstrates how a repurposed, cheap radar module can detect decay in timber.

8:20pm-8:40pm: **Microwave Soil Treatment Alters Soil Biota**

Muhammad Jamal Khan[1], Stephanie D. Jurburg[2] and Graham Brodie[1]
[1]School of Agriculture and Food, Faculty of Veterinary and Agricultural Sciences, The University of Melbourne, Australia [2]Synthesis Centre, German Centre for Integrative Biodiversity Research (iDiv), Germany

Cultural-independent research on soil biota's responses to microwave soil treatment requires attention. This study evaluated the impact of microwave soil heating (75–80°C) on bacterial communities of no-till agricultural soils using 16S rRNA amplicon sequencing. Soil heating significantly reduced the bacterial community richness and the community did not recover to its pre-heating conditions within four weeks. The relative abundance of heat-resistant fast grower bacterial groups increased with soil heating and they remained dominant in the community.

8:40pm-9:00pm: **Examination of Vulcanization of Tire Rubber by Microwave Heating**

K.Okumura[1], A. Saiki[2], M. Hojo[2], T. Takizawa[2], S. Horikoshi[1] [1]Sophia University, Japan [2]Bridgestone Corporation, Japan

The advantages and possible applications of rubber vulcanization using microwaves were investigated. Dielectric properties in vulcanization of each chemical and mixed components were observed using in-situ techniques. In addition, the microwave heating mechanism and conditions for improving the quality of vulcanization by microwave synthesis were examined.

9:00pm-9:20pm: **Development of Microwave Curing Adhesive**

Y. Aari, S. Horikoshi, Sophia University, Japan

The advantage of microwave curing of epoxy-anhydride resin was examined with 2.45 GHz microwave (single mode applicator) and using a microwave method. It was found that there was an interaction between the microwave and the adhesive during the reaction process. The mixing of some microwave responsive materials, such as activated carbon, magnetite, and ionic liquid makes the curing time shorter than additive-free samples.

SESSION: SOLID STATE
Session Chair: Klaus Werner, pinkRF

9:00am-9:30am: **INVITED: Microwave 3.0: Solid State Ovens, Personalization and Mass Customization**
Steven J. Drucker, Droaster Laboratories LLC, USA
Solid state microwave technology innovations linger just over the horizon. Unlike a hurricane, the timing and extent of their landfall remain uncertain. Can solid state oven technology innovations enable the transition from mass production to mass customization, and satisfy consumers' thirst for farm to sofa personalization?

9:30am-9:50am: **Design and Realization of a Very High Power Solid State Microwave Hemp Drying System**
Kenneth Kaplan, Cellencor, Inc., USA
This paper describes the design and implementation of a 400 kilowatt L-band solid state industrial microwave drying system. It is believed to be the first very high power solid state industrial microwave installation in the world. The application is drying freshly harvested industrial hemp, a sensitive high value agricultural product, which is further processed to produce cannabidiol (CBD) oil. Use of solid state microwave generator technology produces a superior quality product, improves energy efficiency, permits a higher level of control integration, and offers outstanding reliability in a critical application.

9:50am-10:10am: **High-Power Remote Plasma Sources and Applied Technologies**
Mohammad Kamarehi, Ken Trenholm, Marco Garuti2, Olivia Keller, [1]MKS Instruments, 2 MKS Instruments/Alter Product, Italy
Microwave and RF Remote Plasma Sources (RPS) are used in semiconductor wafer processing as well as advanced industrial applications. Extensive research has been conducted in understanding the intricacies of the theory and associated technology leading to development and design of viable and practical core technologies for production of high-power Remote Plasma Sources.

10:10am-10:30am: **Design and Testing of an Innovative Solid State RF Portable Device for Curing Resins in the Construction Sector**
F. Dughiero[1], M. Bullo[1], A. Marconi[1] and C. De Massari[2] [1]University of Padua, Italy [2]InovaLab, Italy
One of most time-consuming process in building sector is the chemical fixing of rod or anchor on concrete bases to guarantee high tensile loads. This work presents an innovative radio frequency device that realizes the curing of fixing resins directly on site and needs few minutes.

10:30am-10:40am: **BREAK**

SESSION: MICROWAVE EQUIPMENT AND OVENS
Session Chair: Ray Boxman, Tel Aviv University

10:40am-11:10am: **INVITED: Comparison of Low and High Ripple Magnetron Power Supplies for Microwave Heating Processes**
John F. Gerling, Gerling Consulting, USA
The amount of ripple in the output waveform of magnetron power supplies can affect microwave heating process performance depending on process characteristics and frequency sensitivity. Due largely to the corresponding output frequency spectrum, low ripple power supplies are generally favored for heating high-Q loads while high ripple power supplies may be preferred for bulk material processing.

11:10am-11:30am: **Microwave Oven Output Power – An Overview**
Robert F. Schiffmann, R. F. Schiffmann Associates, Inc., USA
The concept of microwave oven power is elusive, meaning different things. What does it mean to the microwave oven engineer, oven manufacturer, food processor, or consumer? How important is it, how is it used, in what ways is it useful, and what factors influence it? The answers are often surprising.

11:30am-11:50am: **Development and Validation of Analytical Chart for 915 MHz Single-Mode Microwave Assisted Thermal Processing Conditions**
Y. Gezahegn[1], J. Tang[1], P. Pedrow[2], S. Sablani[1], F. Liu[1] and Z. Tang[1]
[1] Biological Systems Engineering Department, Washington State University, USA, [2] School of Electrical Engineering and Computer Science, Washington State University, USA
An analytical chart that relates the food dielectric constant, loss factor, salt content, thickness and preheating temperature with power dissipation and heating rate was developed by using mashed potatoes, peas, and rice as model food. In the validation with 0.6% salt and 22 mm mashed potatoes sample, the temperature at the cold spot was predicted accurately with a 0 to 3% error.

11:50am-1:00pm: **EXHIBITOR SHOWCASE**
Wave PIA, Mini-Circuits, MKS

Wednesday, June 17, 2020

SESSION: FOOD PROCESSING I
Session Chair: Mark Watts, Campbells

9:00am-9:20am: **Interest of Dry Heat Treatment of Wheat Flour by MICRO-WAVE at Low Temperature**
A. Le-Bail[1,4],D. Basto[2,1], G. Diler[1,4], D. Queveuau[1,4], C. Jonchere[3,4], E.A. Norwood[1,4], P. Le-Bail[3,4], J.P. Bernard[5], D. Vennin[5] 1 ONIRIS UMR CNRS GEPEA, France, 2 Università degli Studi di Milano, Italy, 3 INRA-BIA, France, 4 SFR IBSM, France, 5 SAIREM, France
MW (2450 MHz) was applied to wheat flour at temperature of 55-65-75-85-95°C in a domestic batch oven and continuous oven. Results showed that the functional properties of the wheat flour were affected only above 75°C. MW treatment can be considered for disinfection of flours or

reduction of amylase activity as an efficient process in alternative to conventional thermal treatments.

9:20am-9:40am: **Impact of Microwave Heating on Starch Properties and Texture in Sandwich Bread**

Roua BouOrm[12], Vanessa Jury[12], Lionel Boillereaux[12] and Alain Le-Bail[12]
[1]ONIRIS, France, [2]UMR GEPEA, France

The effect of microwave baking (MW) (Sharp oven- 2450 MHz-600W for 6 min) compared to conventional baking (MIWE – Deck oven-at 220°C for 20 min) on starch structure and on staling in sandwich bread was investigated. In MW baked breads, the disruption of starch granules, amylopectin retrogradation and amylose-lipid crystallization were all significantly higher. Therefore, a faster staling was observed with MW baking with a firmer crumb.

9:40am-10:00am: **Microwave: A Solution to Mitigate Checking and Breakage of Dry Cereal Products during Storage**

P. Le-Bail[1,3], M. Bedas[1,3], L. Ribourg[1,3], C. Jonchère[1,3], J.P. Bernard[4], D. Vennin[4], A. Le-Bail[2,3] 1 INRAE-BIA, France, 2 ONIRIS UMR CNRS GEPEA, France, 3 SFR IBSM France, 4 SAIREM, France

In this project, the tracks envisaged to reduce breakage have focused on an approach aiming to better control the state of the matter at the end of cooking and to develop strategies allowing redistribution of water within the matrices at the process exit in order to relax the mechanical stresses that could have accumulated in the product.

10:00am-10:10am: **BREAK**

FOOD PROCESSING II & FOOD SAFETY

Session Chair: Mark Watts, Campbells

10:10am-10:30am: **Comparison of Microwave-Assisted Thermal Pasteurization and High Pressure Processing as Pasteurization Methods for Green Beans**

Sumeyye Inanoglu[1], Gustavo Barbosa-Canovas[1], Mei-Jun Zhu[2], Shyam S. Sablani[1], Frank Liu[1], Zhongwei Tang[1], Juming Tang[1*] [1] Department of Biological Systems Engineering, Washington State University, USA [2] School of Food Science, Washington State University, USA

Green beans were pasteurized by high-pressure processing (HPP; 600 MPa-10 min at 25°C) and microwave-assisted pasteurization system (MAPS; 70°C-2 min) with single-mode 915 MHz cavities. Quality attributes were determined during storage at 2, 7, 10°C. HPP and MAPS resulted in 3.7 and 9–log CFU/g reduction in L. innocua, respectively and the impacts of HPP and MAPS on the quality were similar.

10:30am-10:50am: **Comparison of Microwave and Conventional Thermal Pasteurization of Frozen Green Beans**

Zhi Qu[1], Fang Liu[1], Zhongwei Tang[1] and Juming Tang[1,*] [1]Department of Biological Systems Engineering, Washington State University, USA

Frozen green beans were pasteurized using microwave and water bath. Microwave pasteurized samples had better color and chlorophyll retention after processing and during storage.

10:50am-11:10am: **Antimicrobial Effect of Microwave Treatment on Beef Jerky Inoculated with Salmonella and Listeria monocytogenes**

Darvin Cuellar[1], M.Sc., Don Stull[2], PE, Ayodeji Adeniyi[1], Remio Moreira[1], Alejandro Echeverry, Ph.D.[1] [1]Texas Tech University, USA [2]MicroZap, Inc., USA

Three types (Flavor 1 – 3) of beef jerky inoculated with Salmonella spp. and Listeria monocytogenes, were microwaved, using two different microwaves parameters, Treatment A at 101.7kJ and Treatment B at 170.1kJ. The results showed that treatment A can reduce ~ 2 Log CFU/g of Salmonella and Listeria, and Treatment B can reduce ~ 5 Log CFU/g with high statistical significance (P < 0.001).

11:10am-11:30am: **Gentle Microwave Preservation of Prepared Foods**

B. Wäppling Raaholt[1] [1]RISE Research Institutes of Sweden, Sweden

Microwave HTST processing as described by RISE offers a gentler way to preserve particulate soups, with better maintained texture of root vegetables and nutritional quality. Microwave in-pack pasteurization shows advantages in perceived quality compared to prepared soups that are heat treated conventionally in its packages, at processing criteria to reach the same level of shelf-life.

11:30am-11:50am: **Design of a Small Cavity for Ready Meal to be Inserted in a Vending Machine**

C. De Massari[1], F. Dughiero[2] and A. Marconi[2]
[1]InovaLab, Padua, Italy [2]University of Padua, Padua, Italy

A small heating cavity combining microwaves (1kW magnetron at 2.45 GHz) and infrared to heat up ready-to-eat meals in a vending machine has been designed by numerical simulations. Tests on the designed prototype showed high efficiency (75% average in different conditions) and quality (temperature, uniformity, moisture content) and a short duration of the heating process (less than 90 s): compared with competitors' systems, the process presented better overall results.

11:50pm-12:15pm: **AWARDS & CLOSING REMARKS**
Bob Schiffmann (IMPI President), Graham Brodie (Technical Program Chairman) & Candice Ellison (Student Competition Chairman)

Thursday, June 18, 2020

9:00am-12:00pm **WORKSHOP: SOLID STATE COOKING 101** *(Optional – Additional fee applies)*
Instructor: Klaus Werner, pinkRF (The Netherlands)

The workshop will give an introduction on solid state RF technology in contrast to the legacy magnetron. Aspects like controllability, reliability, frequency ranges, and related basic components to generate the power will be presented. It will be discussed how to apply the "solid state RF" advantages to improved cooking and heating applications at various "processed mass scales". Consequences for system and process design will be addressed.