AMPERE NEWSLETTER

A newsletter devoted to RF & MW heating in the range 1 MHz to 20 GHz Issue 36 ISSN 1361-8598 March 2003

Editor's Comment

This is the first issue of the Newsletter which reaches the members after AMPERE has become a non-profit company. Our status is now recognized throughout the world, and we have a set of rules, the Articles and Memorandum which should govern our activities. Apart from that nothing changes and a letter is attached with this issue informing members of AMPERE that they will be AUTOMATICALLY transferred to the New Company unless they specifically write back to state that they do not wish to join. The next time members will meet is during the Ordinary General Assembly which will take place during the 9th AMPERE Conference at Loughborough University in September.

In recent years Italy has had a very active RF and microwave community and I am delighted to welcome Professor Cristina Leonelli who describes their first National Conference, MISA, 2002. Many congratulations to Cristina for also being able to persuade a number of her colleagues to join AMPERE.

I am extremely pleased to have solicited an article from Professor Steven Bradshaw at University Stellenbosh who describes lucidly their cooperative work on microwave processing of minerals with Nottingham University in the UK. Let us wish both groups our best for such an interesting and worthwhile venture and look forward to reading their results in subsequent issues.

Arrangements for the 9th AMPERE Conference are well under way, so please register early to save some of the costs. Looking forward to seeing as many of you at Loughborough for what promises to be a great meeting. Log on to http://www.lboro.ac.uk/departments/iptme/Ampere9/Index.html for all the details.

Ricky Metaxas
St John's College
Cambridge
UK

FIRST NATIONAL CONFERENCE MISA 2002:

Microwave in Engineering and Applied Science

by Prof.ssa Cristina Leonelli, Universita' degli Studi di Moderna e Reggio Emilia, Modena, Italy

Once more, in the nice environment of Salerno Gulf, the Italian Group of Microwave Applied to Materials and Processes-GIMAMP met during a national conference held on 7-9 November 2002. Only one year has passed from the original foundation meeting of the group held on the Costiera Amalfitana cliffs affording spectacular views. This last meeting attracted nearly 80 scholars and industrialists (20%) and were all gathered in the magnificent conference room of the Cetus Hotel in Cetara (Sa). But it was their common interest on microwave energy which kept them together for the two day conference, starting on the afternoon of the 7th with the greetings from the President of the University of Salerno and the organising committee.

Salerno Gulf

The major effort during the meeting in Benevento in April 2001 of blending together those in electronics and materials souls, lead to a really unexpected success. Not only was the number of orally presented papers high, 32 in all between Friday 8th and the morning of Saturday 9th, but the level of participation was also high.

First the electronic engineers presented their work split into two sessions: *"Modelling"* and *"Applicators & Controlling Systems"* 12 papers in total, followed by the chemists, material and process scientists and industrialists with 20 presentations covering two sessions: *"Chemical Synthesis & Mineralisation"* and *"Environment, Materials & Processes"*.

continued on page 2

Meeting Room

Of the oral presentations 3 were in the form of plenary lectures: "The application of microwave as a heating tool: from the domestic oven to research equipment" presented in a superb and exhaustive way by a professional scientist, Ing. Ruggero Roccari consultant of De Longhi, an appliance producer in Italy. The second plenary talk, entitled "Evolution of high power microwave sources for industrial application", was presented by an Italian producer of power generator for MW sources, Mr. Marco Garuti president of Alter s.r.l of Reggio Emilia. Undoubtedly, the most stimulating plenary talk was given by Prof. Mauro Panunzio, from a CNR Institute of Physics of Macromolecules in Bologna, which presented a very interesting literature review about "Non-thermal microwaves effects in organic chemistry: myth or reality". At the end he also had a number of tests run in his laboratory indicating which are the organic reactions which do not present a kinetic difference from the conventional oil bath heating. A pretty provoking title, this presentation opened the chemistry and material sessions with a huge question mark, which remained in the mind of all the presenters that followed him for the rest of the conference. The researchers most involved in electromagnetic field modelling followed closely the presentations by the chemists and materials scientists with the desire to find some magic. The discussions which followed each presentation were really stimulating with frequent exchanges of ideas between authors and the participants.

After attending numerous microwave dedicated conferences during the past 5 years, Italian researchers finally showed to have worked very seriously on such topics which commonly arise from a number of controversial points, i.e. temperature detection, kinetic rate measurements, yield evaluation, and process energy balance. Their contributions are really significant in many fields and will be collated on a special issue of an international journal and also included on the website of the congress: http://web.tiscali.it/mwitalia/ MISA2002/.

Conference Venue

The only two exhibitors at the meeting, CEM Corp. and MILESTONE, represented the vendors of laboratory equipment on the Italian market.

The other two microwave equipment producers active in the market on an industrial scale, ALTER and SRINT s.r.l., Arezzo, were represented by their Presidents. One telecommunication industry was also present, ITEL Telecomunicazioni, Ruvo di Puglia (Ba), with the demonstration of a huge chamber for treating wood masterpieces, at the Vatican Museums.

GIMAMP held its annual assembly during the conference, just before the sumptuous dinner on Friday in the small village of Cetara. A national school in 2003 was decided upon as well as the venue of the 2004 meeting in Ancona, on the Adriatic coast. The event during 2003 is not going to be organised as extensively as a national meeting in order not to clash with the next AMPERE conference scheduled for September this year at the University of Loughbourough. (See News & Events, page 4)

More information can be found on the Group's website:
http://www.mag.unimo.it/mwit
or contact Prof.ssa Cristina Leonelli
Dipartimento di Ingegneria dei Materiali e dell'Ambiente
Facolta' di Ingegneria
Universita' degli Studi di Modena e Reggio Emilia
Via Vignolese 905/A
41100 Modena
e-mail: leonelli@unimore.it

Collaboration on Microwave Processing of Minerals at the Universities of Nottingham and Stellenbosch

by Prof. Steven Bradshaw
Department of Chemical Engineering
University of Stellenbosch, South Africa

Almost all mineral processing operations make use of comminution, or size reduction, in order to produce manageably sized pieces of ore with which to work, and to liberate the valuable minerals from the valueless, or gangue, material. Electrical energy consumed by comminution processes accounts for approximately 1.5% of total world consumption. This justifies special attention to the energy aspects of size reduction, as improvements in efficiency would give significant process cost savings. In spite of this, the principle of comminution has changed little since ancient times and has been described as "an operation of brute force characterised by extreme inefficiency".

In the search for fundamental changes in the technology, thermally-assisted comminution has been investigated by many workers. In each case it was concluded that the amount of energy required to reduce the mechanical strength of the minerals was greater than the amount of energy reduction achieved. It was noted, however, that several other benefits could be realised, including:

- Increased mill capacity
- Reduced mill wear
- Control of mill product size
- Improved liberation (freeing the valuable mineral from the host rock)
- Reduction in slimes production

In the mid-1980s it was found that in general many valuable minerals were good absorbers of microwave energy, while in general gangue materials were not heated. This suggested that microwaves could achieve differential heating of mineral phases and that thermal stresses generated in this way might be sufficient to cause intergranular cracking. This would lower the required grinding energy and increase liberation of the individual mineral phases. Microwave thermally assisted comminution was first investigated in the 1980s. Most of the testwork carried out to date on microwave-assisted comminution has been at high specific energy consumption and low microwave power, largely predicated by the use of multi-mode microwave cavities. For example microwave energy inputs >45kwht^{-1} were required to reduce comminution energy requirements by 60%. Whilst the influence of microwave radiation from this type of cavity has been shown to have a significant influence in reducing both the strength of ores and enhancing liberation of valuable mineral, the benefits have not been sufficient to justify the cost of the technology.

The Universities of Nottingham and Stellenbosch have made significant breakthroughs in the application of microwave radiation to ore processing. By using single mode cavities and operating at high electric field strength and using short residence times, sometimes as short as 0.1 s, specific microwave energy inputs can be reduced to less than 1kWht^{-1} to give similar reductions in comminution energy. For the first time it is possible that step changes in the energy efficiency of mineral comminution processes may be possible. A patent has been filed and commercialisation of the technology is being pursued formally by the team.

A key part of the research has been the inter-disciplinary nature of the collaboration, blending microwave engineering, mineral processing (led by Dr Sam Kingman at Nottingham), electro-magnetic simulation (involving Prof Steven Bradshaw, Prof Howard Reader, Dr Tse V Chow Ting Chan and Ms Riana Geschke at Stellenbosch) and thermo-elastic simulation (done by Dave Whittles at Nottingham). This enabled far greater understanding of the exact mechanisms of failure in ores of different mineralogy and has identified key design and operating parameters.

The collaboration has picked up pace in the last year with the injection of industrial funding from a major international mining house. Some of the current questions being addressed include:

(1) How can specific microwave applicators be designed which will allow high power density to be developed *and* allow maximum ore throughput to be achieved? It is important that the micro-wave cavity design takes into account the engineering realities of processing industrially relevant tonnages of ore.

(2) How can the interaction of ores and microwaves be modelled in order to gain better understanding of the process and to assess the range of applicable materials without the need for endless test work?

(3) What effects do the benefits of microwave treatment have on process flowsheets and plant economics?

Currently there are five postgraduates and two research fellows working on the project. Of particular importance is the use of modelling to try to address the first two questions.

continued on page 4

Collaboration on microwave processing of minerals at the Universities of Nottingham and Stellenbosch

continued from page 3

Finite difference modelling techniques have been shown by the Nottingham researchers to be particularly powerful in predicting the influence of high microwave power density on ores. The simulations, based on FLAC (finite difference geomechanical software), have shown that the degree and magnitude of thermal stresses generated within microwave treated ores are closely related to the mineralogical texture of the ore but most importantly to the microwave power density.

Finite difference time domain modelling by the Electro-Heating Group at Stellenbosch University has given valuable insight into the maximum power density that can be achieved in different applicators and for different ore types. It has been shown that there exists an optimum mineral grain size for maximum power density. Information from this part of the study will be used by the Nottingham researchers in thermal stress modelling to provide heat source terms required for the different mineral phases. It will also be possible to predict *a priori* which ores are amenable to microwave treatment and what microwave power would be required. This information is considered extremely valuable to the mining industry and the further development of the research.

The true test of the worth of the technology is in the bottom line. Getting to the bottom line will require comprehensive experimental test work. The bulk of the experiments will be done using a 15 kW, 2450 MHz system at Nottingham. The treated ores are then characterised and mineral process simulations will allow benefits to the plant operation to be quantified.

For more information please contact:
Prof. Steven Bradshaw
Director: Unit for High Temperature Materials Processing
Programme Co-ordinator
Department of Chemical Engineering
University of Stellenbosch
Private Bag X1
Matieland 7602
South Africa
Tel: +27+21+808-4493
Mobile: +27+82+7310-965
Fax: +27+21+808-2059
http://www.ee.sun.ac.za/microheat/
http://www.chemeng.sun.ac.za

NEWS & EVENTS

9th International Conference on Microwave and High Frequency Heating, 2nd - 5th September 2003, Loughborough University, UK.
For details contact:
Jon Binner, Professor of Ceramic Materials, IPTME, Loughborough University, Loughborough LE11 3TU, UK
Tel: +44 (0) 1509 223162 Fax: +44 (0) 1509 223949
Email: J.Binner@Lboro.ac.uk or the dedicated conference e-mail address: ampere9@lboro.ac.uk

Please visit also the conference website:
http://www.lboro.ac.uk/departments/iptme/Ampere9/Index.html
It contains information on the Technical Programme, the concurrent Exhibition, the Social Programme, the Sponsors, the Workshop (which will be taking place on the 1st September), the range of accommodation that we have available, how to get to Loughborough and how to register. Regarding the latter, the registration form is now live. It can be filled in on-line and submitted or downloaded as a pdf file and filled in and sent to us by post, fax or email.

Microwave and RF Technology Course
A three day intensive course, directed by RF Schiffmann, will be given at New Brunswick, New Jersey USA between May 28-30, 2003. Details from www.cpfa.comm or phone +1 732 613 4500.

Microwave Assisted Organic Synthesis
For information regarding microwave assisted organic synthesis do visit the following website: www.maos.net which is kept by the Institute of Chemistry at Karl-Franzens Universitat Graz Austria. This site has some interesting information.

The Committee at Work

The photograph captures the newly formed Committee for AMPERE EUROPE LIMITED during its February 2003 meeting at the UKRO in Brussels. From left to right: Jon Binner, Walter Van loock, Alberto Breccia, Cristina Leonelli, John Bows, Monika Willert-Porada, David Sanchez-Fernandez, Peter Puschner, Jose Catala, Georges Roussy.
Inset: Ricky Metaxas and Cristina Leonelli

Case Study

No 3: Microwave clothes drying - on the verge of commercial reality

Introduction

The notion of applying microwave heating technology to consumer laundry appliances was first proposed over a quarter century ago. The economic and technical feasibility had been investigated by various groups since, but major appliance manufacturers were reluctant to pay any attention to these efforts until concerns regarding cost and safety had been addressed. Recent advances in the enabling technologies for microwave clothes dryers have mitigated most or all of the concerns, resulting in serious interest in developing these appliances for the consumer market.

Background

The first known documented conceptualization of a microwave tumble dryer for fabrics was in the mid 1960's by Levinson [1]. A patent assigned to General Electric Company indicates early interest from a major appliance manufacturer [2]. During the mid 1970's, Maytag Company had also expressed interest in the concept, but both companies declined to pursue product development citing perceived high manufacturing costs and difficulties in overcoming the problem of arcing [3].

Throughout the 1980's various individual and collaborative efforts engaged in the construction and testing of prototype dryers, producing several more patents. By this time the potential advantages of microwave drying were well documented and easily demonstrated: faster drying, greater efficiency (30% and 10% more efficient compared to conventional gas and electric dryers, respectively [4]), lower drying temperature and reduced fabric wear [5],[6],[7]. However, most of this work was conducted using clothing articles and materials that are well suited for microwave drying. The hazards relating to arcing and overheating of less ideal clothing articles were also well known, but viable solutions had yet to be developed.

EPRI Prototype Dryers

The Electric Power Research Institute (EPRI) launched a multi-phase program in 1990 to design, construct and test residential, commercial and industrial size dryers.[8] The first EPRI prototype dryer was a laboratory microwave/hot air unit capable of full parametric control and data acquisition. When configured to simulate a residential dryer using 2.5kW of microwave energy and 2.5kW hot air, the results for a typical 3.2 kg load of 50-50 poly/cotton clothes and Turkish towels were 19% faster and 18% more efficient than a conventional electric dryer.[9] However, in the commercial configuration having 6.8kW microwave and 5kW hot air, the results were 58% faster and only 3% more efficient than a conventional electric dryer .

For operation more like conventional dryers, a means to terminate the cycle automatically when the clothes had reached the desired dryness was required. Several methods were investigated for cycle endpoint detection, involving the use of exhaust humidity sensors, fabric moisture contact sensors, cavity field strength probes and fabric temperature opto-pyrometry. Having observed that fabric temperature and field strength correlate well with moisture content, the most suitable and reliable method utilizes IR thermometry and field strength with a fuzzy logic software control algorithm.

Methods to detect potential hazards from metal objects like zippers and coins were also developed. In most cases, it was found that during most of the drying cycle, the electric field strength remained low enough to prevent arcing. However, towards the end of the cycle as moisture neared complete evaporation, the field strength can rise sufficiently to cause overheating, scorching or arcing. A system of selective adsorbent gas sensors was developed to detect minute amounts of pre-combustion vapours in the exhaust stream. In all cases the system was able to terminate the drying cycle long before open flame combustion would occur. From EPRI's perspective the last technical barriers to successful commercialization had been overcome.[10] However, it was not possible to prevent fabric damage entirely for all cases, thus the limitations of microwave clothes drying were becoming more apparent.

Commercial/Industrial Dryers

EPRI investigated commercial and industrial markets for microwave clothes dryers by assessing their economic viability.[11] Since capital cost was perceived as the main obstacle, preliminary designs for large scale dryers were developed. Comparing only the cost factors of 125-pound (dry load weight) microwave and conventional dryers, the costs per load are US$1.97 and US$0.89, respectively, which is hardly attractive to any commercial or industrial user.

However, when savings from extended fabric life are considered, a return on investment is possible depending on the fabric's usage, increased life and replacement cost.

continued on page 6

Case Study

continued from page 5

According to the EPRI analysis, low cost items such as towels and linens required at least 15% improved life for a 2 year ROI, whereas high cost items such as clean room suits yielded a 6 month ROI with as little as 2% extended life. Other examples of high cost fabric items for which early commercial success is most likely are amusement park entertainer uniforms and airline seat covers.

Market research by EPRI indicated consumer interest in the benefits of improved fabric care and shorter drying times, but an overriding aversion to higher costs. However, drying of smaller specialty items was seen as a desirable alternative to dry cleaning, thus a compact microwave dryer appliance was recommended [12]. EPRI contracted Gerling Applied Engineering, Inc. (GAE) in 1997 to develop the concept of a countertop microwave clothes dryer, dubbed "CTMD."

GAE designed and constructed several prototype dryers (see Figure) by merging EPRI dryer technology with well-established microwave oven technology, which would facilitate commercialization by reducing the costs of materials. Having no direct heat source for convective hot air, the CTMD utilizes dissipated heat from the magnetron and power supply to enhance energy efficiency and provide enough warmth to convey the vaporized moisture without premature condensation.

EPRI Countertop microwave clothes dryer

Further improvements to cycle control and hazard detection were developed, and tests indicated drying rates similar to full size dryers. Demonstrations conducted for several major appliance OEMs and in-house evaluations have since led to negotiations for technology licensing [13]. The first real indications of product development activity for a residential microwave clothes dryer appliance seem to imply that the barriers to commercialization of this technology may indeed have been lifted [14].

Some experts in the microwave heating community have doubts about the long term viability of microwave clothes drying while others express optimism by comparing the challenges to those overcome by the microwave oven in its early days. Noting how consumers have accepted and adapted to the microwave oven, an evolution in consumer laundry habits and the birth of an entirely new industry of clothing and laundry products developed expressly for the microwave clothes dryer seems possible.

Thanks are due to John F Gerling (President, Gerling Applied Engineering, Inc., Modesto, US) for providing the details for this case study.

1. M. Levinson, US Patent 3410166
2. D. Heidtmann, US Patent 3439431
3. EPRI Report RP2034-35, Feb 1990
4. R. Tatum, World & I Magazine, 236, Feb 1993
5. T. Koryu Ishii, J. Microwave Power, 389-395, 7(4), 1972
6. R. Strattan, et al, Proc. 26th Microwave Power Symposium, IMPI, 51-52, 1991
7. M. Hamid, J. Microwave Power and Electro-magnetic Energy, 107-113, 26(2), 1991
8. EPRI Report TR-102114, Jul 1993
9. EPRI Report TR-103899, Jul 1994
10. EPRI Report TR-106101, Nov 1996
11. EPRI Report TR-108241, Jun 1997
12. EPRI Report TR-109116, Oct 1997
13. EPRI Technical Brief No. 1006408, Dec 2001
14. E. Spagat, "Whirlpool Goes Portable to Sell Dryers to Gen Y," Wall Street Journal, June 4, 2002

John Bows, Unilever Research Colworth, UK

Your news and views are always welcome

Please write to the Editor:

Dr Ricky Metaxas
Electricity Utilisation Group
St John's College, University of Cambridge
Cambridge CB2 1TP, UK
Tel: +44 1223 338646 Fax: +44 1223 337720
Email: acm33@cam.ac.uk

www2.eng.cam.ac.uk/~acm/eug.html
www.ampereeurope.org

AMPERE Subscription Rates

Europe:	1 year	£30.00
	2 years	£50.00
Worldwide:	1 year	£35.00
	2 years	£60.00

Contact:
Dr Ricky Metaxas, Electricity Utilisation Group, St John's College
University of Cambridge, Cambridge CB2 1TP, UK
Tel: +44 1223 338646 Fax: +44 1223 337720
Email: acm33@cam.ac.uk
www2.eng.cam.ac.uk/~acm/eug.html
www.ampereeurope.org