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Localized microwave-heating (LMH) studies at Tel Aviv University

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Abstract

This article presents a two-decade perspective of localized microwave-heating (LMH) research and related studies conducted at Tel-Aviv University (TAU). These contributions included conceptual, experimental and theoretical studies of thermal-runaway instabilities and hotspot formation effects, microwave drilling and cutting, basalt melting, LMH of metal powders for 3D printing, thermite ignition, and dusty plasma ejection in forms of fire-columns and fireballs. Recently we have discovered the effect of DC-LMH synergy in metals, which enables deep cutting of iron bars.

The TAU-LMH lab

Since established in 1991, our research laboratory at TAU has been devoted to microwave-energy studies, in both aspects of power generation and microwave impact phenomena.

The first years were mostly dedicated to research and development (R&D) of high-power microwave (HPM) generators. These mainly included novel versions of fast-wave devices, oscillators and amplifiers, such as cyclotron-resonance masers (CRM's or gyrotrons) [1] and free-electron masers (FEM's or ubitrons, also known as long-wavelength free-electron lasers, FEL's) [2]. Our main paradigmatic idea then was to incorporate slow-wave features (as in traveling-wave tubes, TWT's) into the operating mechanisms of fast-wave CRM and FEM devices [3, 4]. These conceptual combinations resulted in compact hybrid schemes of microwave tubes with potentially improved HPM capabilities. Following our early studies on novel microwave generators, the main challenge facing our work has been naturally shifted toward finding new applications for the generated microwave power.

Consequently, we started to work on more applicative industrial projects, such as microwave drying of rapid ink-jet printing processes, microwave greenhouses for agricultural purposes [5], and microwave drilling [6]. These application-oriented R&D projects have led us into more fundamental studies on localized microwave-heating (LMH) effects, thermal-runaway instabilities, and hotspot formation [7]. These were later embodied in various LMH phenomena and applications, such as the microwave drill [6, 8], plasma ejection in fireball and fire-column forms [9, 10], additive solidification of metal powders toward 3D-printing (3DP) by LMH [11-13], thermite ignition [14, 15], basalt melting [16-18], and microwave-induced breakdown spectroscopy (MIBS) [19]. More recently, our discovery of the DC and LMH synergy has yielded a capability of iron melting and cutting by DC-LMH, as described below.

Microwave drills and solid-state LMH

The high energy-density obtained in the various LMH processes enables HPM-like effects at relatively low levels of microwave input power (even under ~100 W). Therefore, we adopted solid-state generators for LMH applications already in the early 2000's years (mostly LDMOS transistors, used then in cellular base-stations) [20-22].

The solid-state technology opened new possibilities for LMH devices, which seemed to provide compact, low-cost substitutes for laser-based techniques for some applications. The microwave drill, for instance, intentionally utilizes the LMH effect by purposely exciting a thermal-runaway instability [6, 8, 22, 23]. As shown in **Figure 1**, it generates a small hotspot (in the order of 1 mm in diameter, ~10^2 times shorter than the microwave wavelength), which increases the local temperature up to >1,000ºC, in heating rates of >100ºC/s. LMH effects have been demonstrated by microwave drilling and cutting into concrete, as well as melting and drilling effects in ceramics, basalts, glass, polymers, bones [24], silicon, and other materials [25]. Likewise, an LMH doping effect in silicon was demonstrated [26]. It was also shown that LMH may generate dusty plasmas in forms of fire-columns and fireballs, directly from solid substrates to air atmosphere [9, 10], and to produce nano-particles from the substrate materials [27-29].

A theoretical, coupled thermal-electromagnetic model of the sub-wavelength LMH interaction confirmed the hotspot evolution in front of the open-end applicator due to the intentional thermal-runaway instability [23].

The role of the temperature-dependent material properties on the confined heating process was identified, and the consequent variation in the load impedance was quantified, due to the spatiotemporal temperature evolution and the varying geometry. The theoretical analysis provided both, an insight to the physical principles of the LMH mechanism, and a valid model for LMH-applicator design and its operational monitoring.

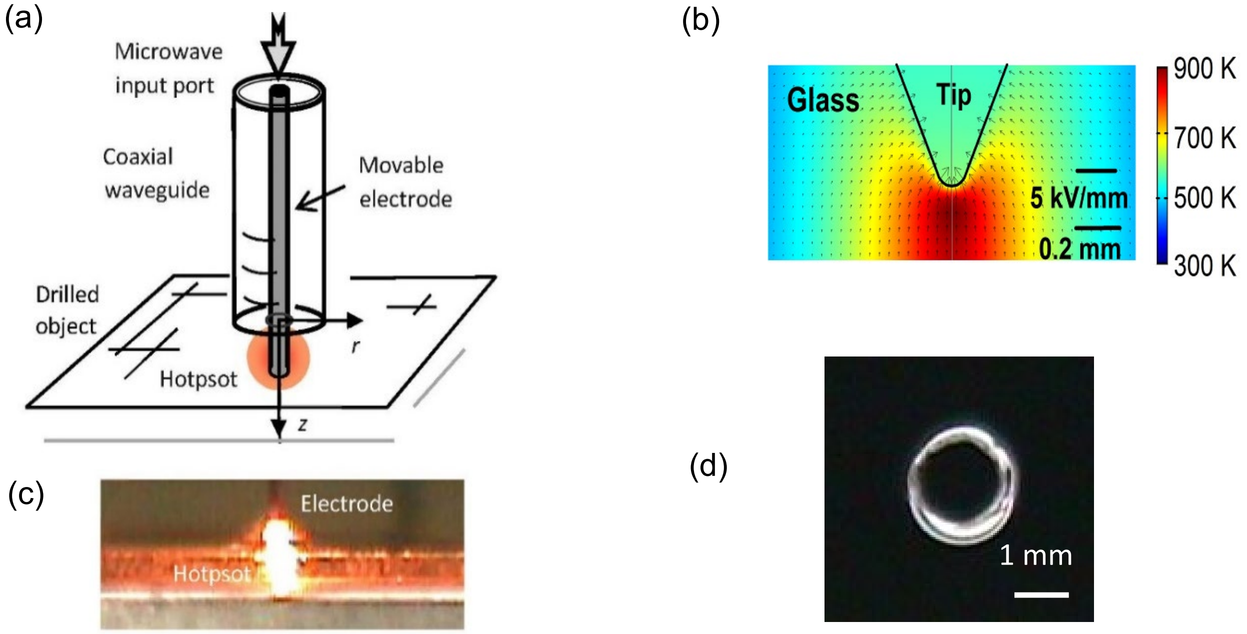

Figure 1. The microwave-drill [6, 22]: (a) A simplified illustration of a basic microwave-drill applicator, consisting of a coaxial waveguide and a moveable center electrode. (b) A simulation of the spatial temperature and electric-field distributions at the hotspot in front of an LDMOS-based microwave-drill. (c) A hotspot created in a glass plate by a 1-mm$^{\varnothing}$ electrode microwave-drill. (d) A ~1.6-mm$^{\varnothing}$ hole made by a microwave drill in glass.

Advanced microwave-drill schemes enable wider operating ranges, including hole diameters from ~0.5 mm in glass up to 12 mm in concrete (the latter in >20 cm hole depths) [30], as well as cutting of concrete and iron rebars [31, 32]. Microwave drilling has also been demonstrated on various ceramics (e.g., low-purity alumina, mullite-cordierite, glass-ceramics and thermal-barrier coating) [33, 34].

LMH in cavities, hotspot excitation, basalt melting, and miniature volcano's

LMH intensification due to temperature-dependent material properties has also been demonstrated by irradiating basalts in a microwave cavity [16-18, 35].

The LMH effect is clearly seen as the basalt brick is melted inside, while its outer surface remains solid, as shown in **Figure 2**. The molten core ejects lava outside the brick, which leaves a void inside (whereas the outer surface of the brick remains solid). A numerical simulation agreed well with the temperature profiles measured on the basalt-brick faces. Similar demonstrations were also conducted with naturally shaped basalt stones, to mimic various volcanic phenomena in a laboratory scale. This LMH effect can be further used in order to intensify processes of mineral extraction from rocks.

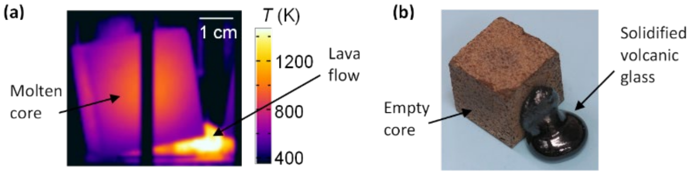

Figure 2. A basalt brick irradiated in a microwave cavity [17]: (a) The intensified LMH melts only the core, as observed through the porous surface, which remains solid. The lava flow ejected from the core tilts the brick in the cavity. (b) The hollow brick with the lava solidified to volcanic glass (obsidian).

Metal powder LMH, additive manufacturing (AM), and thermite ignition

In metal powders, the LMH effect is also associated with internal micro-plasma breakdowns between the particles, which expedite the local melting and solidification of the metal powder. This effect enabled LMH-based techniques for stepwise or continuous 3DP and AM of metal parts from various powders [11-13], as shown in **Figure 3**.

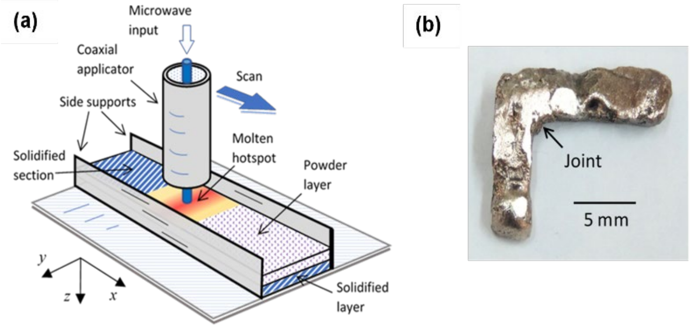

Figure 3. LMH-AM experimental [13]: (a) A conceptual scheme of the experimental 1D scanning-LMH-AM process. The powder is applied in layers, each is scanned and solidified by the LMH applicator, and bonded to the underlying, previously solidified layers. (b) An L-shape metal rod fabricated by two straight rods, each produced by scanning LMH-AM and joined together by a powder-batch LMH.

Powder mixtures, as made of pure aluminum and magnetite (or hematite), may generate energetic thermite reactions, as shown in **Figure 4**. These effects could be useful for a variety of combustion and material processing applications. However, their usage was limited by the difficult ignition of these reactions. We found that ignition of thermite reactions could be feasible by intensified LMH in air [14] as well as underwater [15].

In our LMH-ignition experiments, the power required for thermite ignition, ~0.1-kW for a ~3-s period, was provided by a solid-state microwave generator. Our experiments also demonstrated the feasibility of cutting and welding by relatively low-power LMH.

The initiation of the intense exothermic reaction in thermites also demonstrated an example for LMH ignition of other self-propagating high-temperature syntheses (SHS). Due to their zero-oxygen balance, exothermic thermite reactions also occur underwater. This feature was also impeded by the hydrophobic properties of the thermite powder and its tendency to agglomerate on the water surface, rather than to sink into the water. However, we discovered a bubble-marble (BM) effect that enabled the insertion and confinement of a thermite-powder batch into water by a static magnetic field, and its ignition by LMH underwater [15]. Potential applications of this underwater combustion effect may include wet welding, thermal drilling, detonation, thrust generation, material processing, and composite material production. All these could be implemented as well in other oxygen-free environments, such as the outer space. Chemical reactions applied by LMH for surface treatments also include thermite reactions for the conversion of rust, to iron and alumina [14].

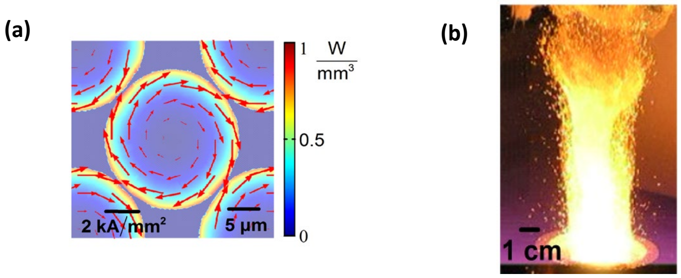

Figure 4. LMH of metal powders: (a) Eddy currents induced in copper powder by LMH. (b) A thermite flame ignited by LMH intensification [14].

Dusty plasma and fireball ejection by LMH

Dusty plasmas in forms of fireballs and fire-columns, as shown in **Figure 5**, were found to be ejected by LMH directly from hotspots evolved in solid substrates, as presented in [10, 18, 27-29] for various dielectric and metallic materials.

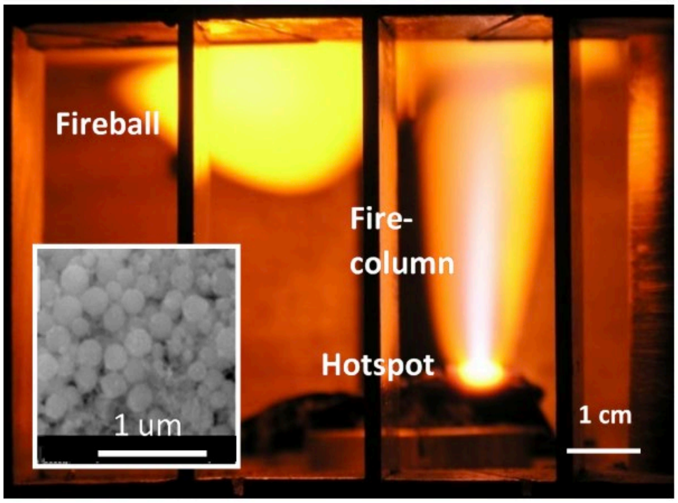

Figure 5. Plasmoids ejected from an LMH hotspot in glass [29], including the intensified hotspot in the solid substrate, the fire-column ejected, and the secondary fireball evolved (all were captured together, but each may solely exist in its own operating mode). The inset shows nano-particles produced by LMH generated dusty plasma, as observed by SEM.

The intensified LMH-plasma process begins with a hotspot formation as in microwave drilling. However, for plasma ejection, the electrode is lifted up (rather than pushed in) in order to detach the molten drop from the surface and to further inflate it to a form of a buoyant fireball.

Beside their resemblance to natural ball-lightning phenomena, fireballs and fire columns, may also have a practical importance, for instance as means to produce nano-particles directly from various substrate materials (silicon, glass, ceramics, copper, titanium, etc.) [27-29].

Nanoparticles were observed in these experiments by both, *in-situ* synchrotron small-angle X-ray scattering (SAXS) of the dusty plasma, and *ex-situ* SEM observations of the nano-powders collected after the processes. The LMH generated plasma-column, ejected from the hotspot induced in the substrate material, can also be used for atomic emission spectroscopy of the light emitted by the plasma. Hence, we proposed the microwave-induced breakdown spectroscopy (MIBS) technique [19], similar to the laser-induced (LIBS) identification technique (except that the plasma is excited by LMH rather than by laser).

LMH of silicon-wafer experiments yielded heating rates of >200 K/s up to the melting point [29]. This enabled localized thermal processes in silicon, including joining, welding, drilling, and doping. The latter was demonstrated by local doping of silicon substrates by LMH, using silver and aluminum dopants [26]. The dopant was incorporated in these processes in the electrode tip, and locally diffused into the heated wafer to form a sub-micron PN junction.

DC-LMH hybrids, iron melting and cutting, and natural lightning effects

Following our previous LMH studies, we have recently discovered that adding a relatively small direct-current (DC) to LMH may catalyze a hotspot effect in bulk iron, up to a local melting (and even further to ablation and dusty-plasma ejection) [32].

This combined DC-LMH effect has been demonstrated for instance by cutting an 8-mm$^{\varnothing}$ iron rebar (carbon steel) without any susceptor added. Such a deep melting effect as shown in **Figure 6** is not feasible otherwise in these conditions, neither by sole microwaves nor by sole DC.

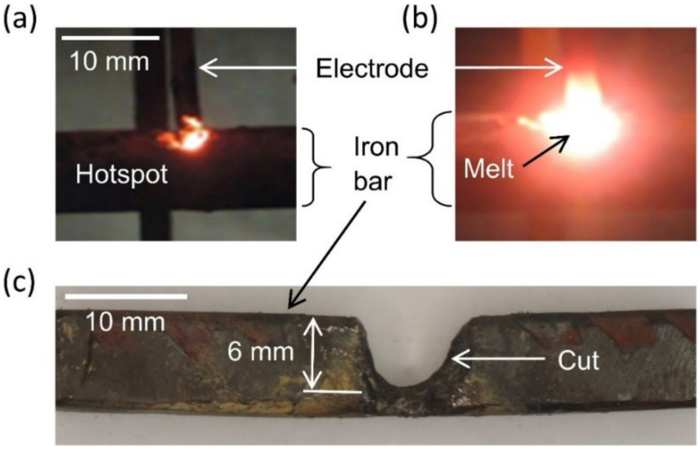

Figure 6. Iron melting and cutting by DC-LMH [32]: (a) The hotspot formed by the combined LMH and DC in the iron rebar; (b) the deeper melting obtained, and (c) the cut performed by DC-LMH in the iron rebar (the joint was intentionally remained).

This synergic effect is attributed to a combined thermal skin evolution, which jointly forms a hotspot by a mutually intensified DC-LMH thermal-runaway instability, and inherently deepens the microwave penetration into the bulk iron.

The DC-LMH effect in metals is hypothesized in general as conceptually illustrated in **Figure 7** [32]. In this scheme, a bulk of metal, with a temperature-dependent electric conductivity, is subjected to both microwave irradiation and a DC flow (I_{DC}) across it.

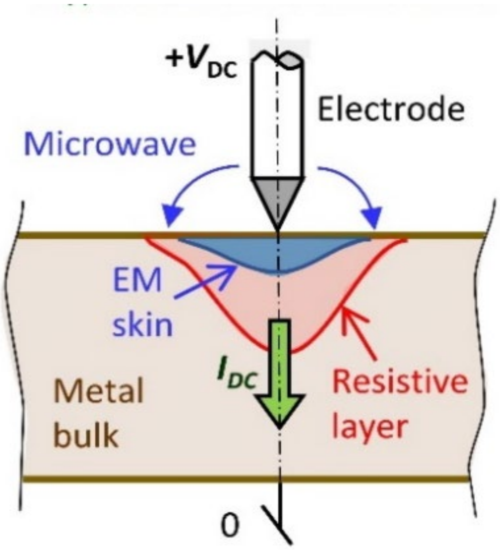

Figure 7. The hypothesized DC-LMH combined interaction in metal bulks [32].

The microwave is guided by a perpendicular electrode towards the metal plate (as in a microwave drill [6]). In this scenario, neither the DC alone nor the sole microwave irradiation (in equivalent power levels) may heat up the metal bulk. However, by combining the two, the heat energy dissipated in the EM skin region is diffused into the bulk beyond the skin depth, and further reduces its electric conductivity. Therefore, the initial microwave heating confined within the EM skin depth creates a deeper thermal resistive layer for the DC, due to the elevated resistivity of the hotter metal region. The deeper resistive layer, broadened beyond the EM skin-depth, absorbs more of the DC power and hence expedites the further expansion of this layer. The DC Joule heating is dissipated deeper than the EM skin, and further rises the temperature therein (which enables a deeper penetration of the microwave heating and hence a hotspot formation by a synergic DC-LMH thermal-runaway instability).

This synergic DC-LMH effect may intensify the combined heating process in a positive-feedback fashion, namely by a joint thermal-runaway instability, and hence forming a molten hotspot deeper in the metal bulk.

DC-LMH synergy is also obtained in dusty-plasma ejection from basalt [18]. In this experiment, after the initial stage of LMH ignition, the plasma is gradually transferred to a form of a stably sustained, long-lived fire-pillar, solely maintained by the DC supply. A stepwise transitional process was applied in order to initiate a steady column, as shown in **Figure 8** [18].

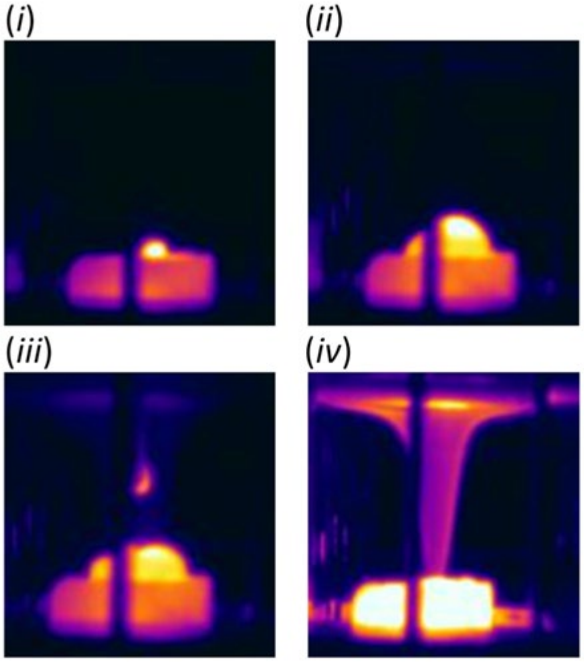

Figure 8. Thermal images of the LMH-to-DC transition in basalt [18]: The hotspot evolution by LMH (*i, ii*) is intensified by DC (*iii*). The ejected plasma column is solely sustained by DC (*iv*).

In **Figure 8**, the hotspot is formed by an LMH thermal-runaway effect (*i*), and the inner basalt core is molten (*ii*). Then, the hotspot is further intensified by applying a DC current (by an electrode) to the conducting molten channel formed inside the isolating solid substrate (*iii*). Once the DC channel is established, a plasma column is ejected from the molten hotspot to the air atmosphere, and the electrode is lifted upwards whereas the dusty-plasma section interacts with the microwave irradiation and closes the DC-circuit loop. Finally, the microwave is turned off, leaving a stable DC current in the serial circuit (*iv*). This LMH ignition process creates a self-sustained, steady dusty-plasma column, in a form of a fire-pillar, solely maintained by a DC supply.

We have studied this finding [18] with respect to two different themes. One refers to material-processing aspects of rocks and minerals using microwave-assisted techniques. The other theme is related to the resemblance of microwave-excited fireballs to rare ball-lightning (BL) phenomena (also associated with volcanic eruptions).

The known resemblance between microwave-excited plasmoids and BL phenomena is further confirmed here by the LMH-to DC transition effect [18], since DC sources are more readily available in nature, as provided for instance by charged clouds with similar electric-field intensities (in the range $>10^3$ V/m), as illustrated in **Figure 9** [18].

The LMH-to-DC-transition applied here may provide a more comprehensive analogy between laboratory observations and natural phenomena (compared to sole RF models). It may suggest a merge of internal and external energy theories for BL (possibly with another local heat source as a starter).

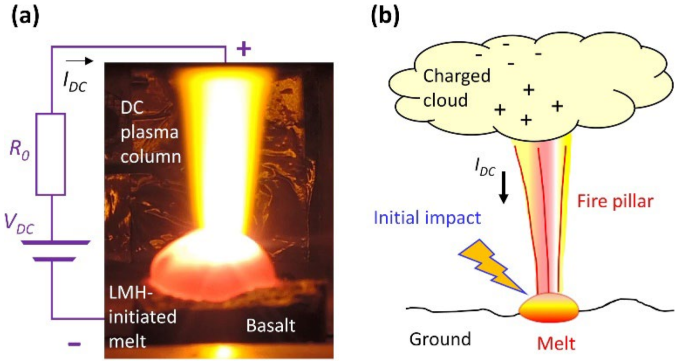

Figure 9. Analogy to rare lightning effects [18]: A seeming analogy between (a) the experimental, DC-sustained dusty-plasma column emitted from basalt, initiated by an LMH-to-DC transition, and (b) a natural, fire-pillar-like lightning, sustained between an electrically-charged cloud and a melt on the ground (initially caused, for instance, by a normal-lightning impact, which may create a ball lightning [18]).

LMH vs. lasers, and concluding remarks

The LMH intensification technique can be considered, to some extent, as a low-end substitute for laser-based processes, such as drilling and cutting, joining, surface treatment, material identification, and additive manufacturing.

While LMH may provide low-cost, compact and efficient solutions in this regard, it requires a physical contact with the object (unlike the remote laser), and its resolution (~1 mm) is yet inferior with respect to lasers. Therefore, one may deduce that LMH applications, such as the microwave drill, are more relevant to operating regimes of relatively large volumes and rough processes, or as complementary means to the more accurate and expensive laser-based systems. Nevertheless, LMH and DC-LMH concepts, and the research outcomes of their further investigations, may form new paradigms of hybrid thermal processing of various materials, in solid, powder, and plasma phases.

Acknowledgements

The LMH studies described here were supported by the Israel Science Foundation (ISF) and the Israeli Ministry of Science and Technology (MOST). The valuable contributions of research students, partners and colleagues (as indicated below in the references' authorship) are warmly acknowledged. The author also thanks the AMPERE-Newsletter's Editors for the invitation to present this summary.

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About the author

Eli Jerby received his Ph.D. degree in Electrical Engineering from Tel Aviv University (TAU) in 1989. As a Rothschild and Fulbright post doctoral fellow, he worked at MIT with the late Prof. George Bekefi. Since his return to TAU in 1991 as a faculty member, Prof. Jerby has studied novel schemes of free-electron and cyclotron-resonance masers (FEM's and CRM's, respectively), as well as localized microwave heating effects and their applications, including the microwave-drill invention, additive-manufacturing (AM) of metal powders, microwave-generated plasmas and fireballs, thermite reactions and metallic-fuel ignition by localized microwaves. Besides his scientific work, he has conducted several projects for the industry, government, and start up initiatives. Prof. Jerby served as a program-committee member of int'l conferences and workshops worldwide, in the fields of plasma, radiation sources, microwave heating, and microwave discharges. He also served as the Editor of JMPEE, the Journal of Microwave Power and Electromagnetic Energy (2006-2009) and of AMPERE Newsletter (2015-2017). More information and his publications are available at http://www.eng.tau.ac.il/~jerby

Microwave Industrial Solutions (MIS)

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To be Managing Director and one of the owners of SAIREM during the past 40 years was a great adventure, an amazing era. I spent a lot of time promoting SAIREM word-wide reaching 90% of the turnover in export sales.

I participated at many AMPERE or IMPI conferences where I met great people as well as promoting the MW technology like Ricky Metaxas, Georges Roussy, Andre Jean Berteaud and Serge Lefeuvre, as academic people or Bernie Krieger and Bob Schiffmann as industrialists. I can't write all the names of the fascinating people I met because the list will be too long.

I was on the Board of IMPI for many years and I am still on the Board of AMPERE.

Since my time in the MW laboratory at the University of Lyon, I have enjoyed and was very excited to work on MW technology because there are always so many new opportunities,

On February 2018 we decided to sell SAIREM in order to continue to increase the business in the future via a new owner. At that time the turn-over was 10M€. David Vennin became the new President of SAIREM.

I created my consulting company MIS (MICROWAVE INDUSTRIAL SOLUTIONS) but agreed to remain with SAIREM for 5 years to transfer my knowledge, my expertise and the history of the company to the new owner. I enjoyed training the commercial and laboratory staff at SAIREM explaining how to calculate the size of industrial machines following some tests in the laboratory, to transfer my expertise on different subjects, etc. Further, I loved to introduce SAIREM staff to the people I have met during the MW conferences and travelling round the world. My contract with SAIREM ended in February 2023.

The future of MW technology (RF as well) will continue to grow. This is why in parallel of my work at SAIREM, via MIS, I started some consultancy work to assist labs and industrialists to improve their knowledge on MW and RF technologies. Further it was important to carry out some tests on industrial machines that companies have bought where they have a number of problems, to organize staff training, and so on….

I will continue to promote MW and RF technologies during the next few years. There is still much to be done.

About the author

J P Bernard completed his degree in Electrical Engineering at the University of Lyon in 1976 -1977 and joined Prof Jean Pierre Pelissier' s group working towards his doctorate. SAIREM was created in 1978 and Jean Paul joined the company as a shareholder, became Managing Director in 1982 and stayed until 2018. He then established his new consultancy MIS while at the same time remaining with SAIREM for 5 years to assist in the transition.

Why Microwave Technologies Consulting?

Marilena Radoiu

Founder at Microwave Technologies Consulting
Contact E-mail: marilena.radoiu@btinternet.com

My educational background includes an MSc in Technological Organic Chemistry and a PhD in Radiochemistry & Nuclear Materials from the Polytechnic University of Bucharest. It was during my PhD that I discovered microwaves, their applications and the AMPERE organisation.

My PhD thesis, although directed by the Polytechnic University of Bucharest, involved a very challenging hands-on project of exhaust gas treatment by accelerated electron beams at the Institute of Atomic Physics (IAP) in Bucharest for which I was working as a newly appointed research scientist. One may think there is a long way between the ionizing radiation produced by a 10 MeV linear electron beam accelerator (LINAC) and the non-ionizing radiation coming from a simple 'kitchen' magnetron yet, I shortly discovered that our LINAC was accelerating the produced electrons through a number of monomode resonant cavities operated at 3 GHz. The idea of building a hybrid chamber that made possible to treat the exhaust gas by a combination between the LINAC's accelerated electron beams and the microwaves emitted by a 2.45 GHz magnetron was the novelty of my thesis [1] and was made possible by Dr. Diana Martin with whom I collaborated at the IAP and who made me resonate at 2.45 GHz. Diana trusted my chemistry skills and we were microwaving everything – from waste wine distillation to polymers for wastewater treatment, to hybrid electron beam-microwave plasmas for exhaust gas treatment and so many other applications 'just for curiosity'. Needless to say that my first equipment was a kitchen oven 'adapted' by Dr. Martin – it had shielded chimneys to introduce glassware and it had a tabletop variac for adjusting the microwave power! This was the equipment that sent me to my first AMPERE conference in Fermo, Italy where I presented work related to microwave assisted catalysis en liquid phase. The paper earned me a student award and the great privilege of meeting Dr. Milan Hajek who invited me to join his catalysis group at the end of my PhD. A year after, a second PhD at Kingston University, Ontario, Canada within the group of Prof. J. Wang gave me the possibility to work in a microwave-assisted plasmas research project funded by an industrial group, which gave me the microwave plasma expertise and the invitation to join the R&D team of BOC Edwards U.K. at the beginning of 2001 and Sairem, France at the end of 2008.

I created Microwave Technologies Consulting (MTC) [2], in February 2018. I had just graduated from Ecole de Management Lyon (EM Lyon) where I fast-tracked an Executive MBA that waved me towards entrepreneurship. Having dedicated over 25 years to microwave applications, the foundation of a consultancy devoted to microwave applications for the industry and for the young came to me as a must do. Despite my involvement with the industry, I always tried to find recipes for being involved with academics, trying to pass my knowledge on to young Master or PhD students.

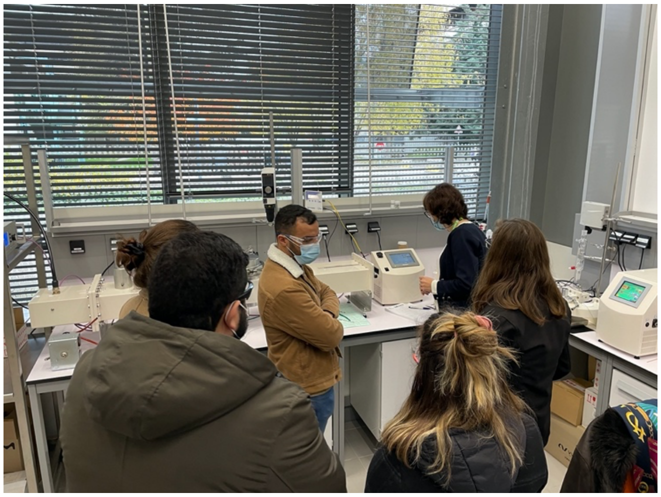
Teamed with Mr. Ariel Mello, Technical Director of MTC, we collaborate with academia and businesses of all shapes and sizes globally. In our microwave laboratory hosted by Axel'One (www.axel-one.com), Lyon, France, Ariel and I are convinced that our role is to connect science and business, innovation and commercialization to educate young generations as to bring bright ideas and research into the marketplace.

We dedicate our time to understanding and optimising microwave-assisted processes to enable timely process development in line with project demands, from basic R&I approach through to development and life-cycle management.

Finally, I am very proud that my microwave related work has been acknowledged several times, by both the launch of microwave-assisted processes/equipment for the industry and by awards, including two very special to me, from my peers AMPERE fellows:

- Rustum Roy Award, 3rd Global Congress on Microwave Energy Applications, Cartagena, Spain, 28th July 2016;
- AMPERE 2019 Medal, Valencia, Spain, 12th September 2019;
- Trophees des Femmes de l'Industrie, Femme de R&D / R&D Woman award, Paris, France, 24th September 2019;
- Rennes Innovation Award 2011 for Equipment & Technology;
- Chartered Chemist and Chartered Scientist of the Royal Society of Chemistry since 2005.

R&D Woman award, Paris, France, September 2019



Hands on with Master students, December 2021

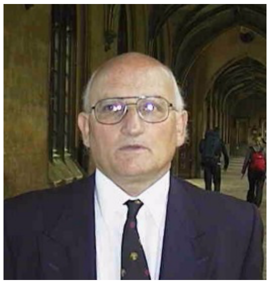
Least but not last, I am proud that microwave heating and microwave plasmas are technologies that are starting to be acknowledged by the world and by the EU as industrial solutions to a greener industry by their role in process electrification. '*…Integrate existing highly efficient technologies, e.g., induction heating, hybrid operation between electric heating and zero-carbon fuel heating* ***microwave and plasma technologies,*** *electric resistances, and/or the combination with digital technologies or hybrid modelling…'* [3].

For further reading

1. M. Radoiu, D. Martin, I. Georgescu, I. Calinescu, V. Bestea, I. Indreias, C. Matei, "A laboratory test unit for exhausted gas cleaning by electron beam and combined electron beam - microwave irradiation", Nucl. Instrum. Physics Research, B, 139, p.506-10, 1998, 10.1016/S0168-583X(97)00977-4.
2. www.microwavetechs.com
3. https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/horizon-cl4-2023-twin-transition-01-33

Ricky's Afterthought:

UK's Prime Minister aims to turn the UK into a Science and Technology Superpower



A.C. (Ricky) Metaxas

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In Issue 112 I reported on the demise of the European Horizon funding scheme for UK based-researchers. They were excluded and those that were awarded grants were told that they had to move back to Europe in order to continue benefiting from the scheme. It is not clear whether, now that great strides have been made by the Prime Minister (PM) Richi Sunak on the Northern Ireland Protocol, Europe may reverse its decision and allow the original funding to continue.

However, the newly formed Science, Innovation and Technology Department, headed by 38 year old Michelle Donelan and strongly backed by the PM, announced major funding evidently to boost UK based researchers to compete globally with other countries, notably USA, China and the European Union. How does this new funding stand with the Industrial Strategy Challenge Fund launched some 7 years ago by the then PM, Theresa May, which promised to support businesses to the tune of £700 million working on cutting edge technologies such as AI and robotics is not at all clear. The Strategy Fund is managed by the Engineering and Physical Sciences Research Council (EPSRC). By now some of the initial projects must have come to fruition and it would be interesting to read the consensus of the scientific community as to the success rate.

Never the less the Press Release from 10 Downing Street on Monday 6 March 2023 read as follows:

The Prime Minister and Technology Secretary today launched the government's plan to cement the UK's place as a science and technology superpower by 2030.

Bold plan to grow the UK Economy, create high-paid jobs of the future, protect our security and radically improve peoples lives through science, innovation and technology outlines.

The plan will bring every part of government together to meet one single goal: to cement UK's place as a global science and technology superpower by 2030. Backed by over £370m in new government funding to boost infrastructure, investment and skills for the UK's most exciting growth technologies from quantum and supercomputing to AI.

The new Science and Technology Framework is the first major piece of work from the newly created Department for Science, Innovation and Technology and will challenge every part of government to better put the UK at the forefront of global science and technology this decade through 10 key actions – creating a coordinated cross-government approach. In doing so, the government will foster the right conditions for industry innovation and world leading scientific research to deliver high-paid jobs of the future, grow the economy in cutting-edge industries, and improve people's lives from better healthcare to security.

The ten points of the new Science and Technology Framework focus on:

- identifying, pursuing and achieving strategic advantage in the technologies that are most critical to achieving UK objectives
- showcasing the UK's S&T strengths and ambitions at home and abroad to attract talent, investment and boost our global influence
- boosting private and public investment in research and development for economic growth and better productivity
- building on the UK's already enviable talent and skills base
- financing innovative science and technology start-ups and companies
- capitalising on the UK government's buying power to boost innovation and growth through public sector procurement
- shaping the global science and tech landscape through strategic international engagement, diplomacy and partnerships
- ensuring researchers have access to the best physical and digital infrastructure for R&D that attracts talent, investment and discoveries
- leveraging post-Brexit freedoms to create world-leading pro-innovation regulation and influence global technical standards
- creating a pro-innovation culture throughout the UK's public sector to improve the way our public services run

The delivery of this new Framework will begin immediately with an initial raft of projects, worth several hundred million pounds in new and existing funding, which will help ensure the UK has the skills and infrastructure to take a global lead in game-changing technologies.

The Prime Minister stated that "trailblazing science and innovation have been in our DNA for decades. But in an increasingly competitive world, we can only stay ahead with focus, dynamism and leadership. The UK will use the post Brexit freedoms to pursue pro-innovation regulations and encourage a pro-innovation culture. The more we innovate" continued the PM, "the more we can grow our economy, create the high-paid jobs of the future, protect our security, and improve lives across the country."

The Secretary of State in a radio interview on Tuesday 7 March stated that the scheme will head hunt talented researchers and encourage them to move to the UK to be eligible for this funding. Visas will be made available through the existing scheme for skilled workers but whether these individuals will be able to be accompanied by their families remains to be seen. Who will carry out the head hunting to identify the key researchers was also a point needing clarification.

Michelle Donelan stated, "Innovation and technology are our future. They hold the keys to everything from raising productivity and wages, to transforming healthcare, reducing energy costs and ultimately creating jobs and economic growth in the UK, providing the financial firepower allowing us to spend more on public services" and continued, "that is why, today, we are putting the full might of the British Government and our private sector partners behind our push to become a scientific and technological superpower, because only through being world-leaders in future industries like AI and quantum (computing) will we be able to improve the lives of every Briton."

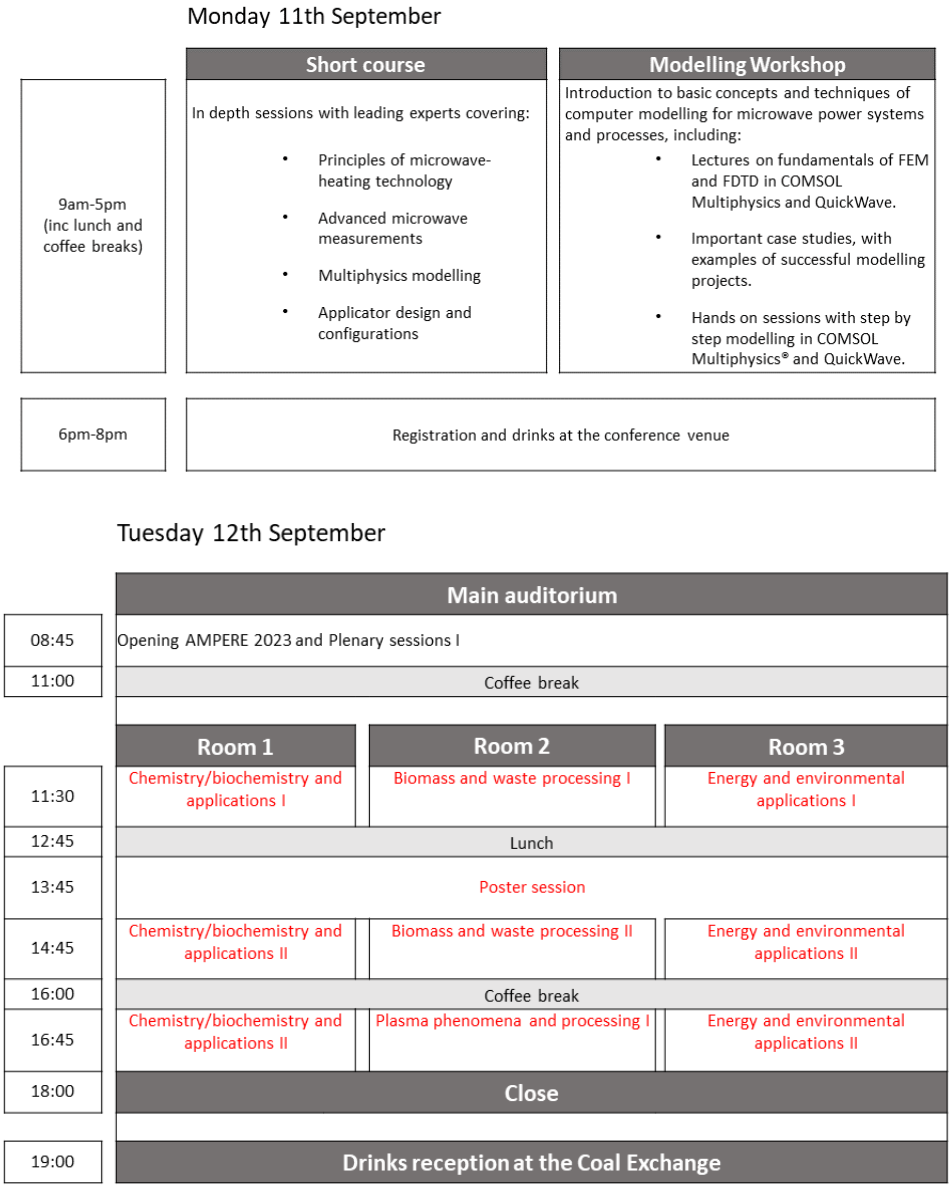
One caveat, however, is that on May 23 of this year, the government announced that from May 2024 foreign students either undergraduates or pursuing an MSc they will not be able to bring their dependents into the UK. PhD students are exempt this new restriction. It is not clear that this will apply to foreign research staff which companies in the UK may be interested in recruiting to fill positions not able to recruit from the UK.

Professor Martin Rees, Astronomer Royal, Fellow of Trinity College, Cambridge and co-founder of the Centre for the Study of Existential Risk* concurs that this is a major initiative and argues that the UK must not fall back on its science and technology innovation stance built over many years. Sir Paul Nurse, director of the Francis Crick Institute, published a review on UK science and he too agrees with the PM's initiative that science and technology is the key to maintaining UK's position in the lead countries in this area. The UK will initially fund projects in AI, quantum technology and engineering biology to the tune of £230 million.

One has to applaud such an initiative, however, its success lies in fulfilling the pledges made and on the staff that will carry out the ground work in getting this scheme off the ground.

*Concerned with extinction-level threats posed by present or future technology.

AMPERE 2023 Conference programme



Monday 11th September

	Short course	Modelling Workshop
9am-5pm (inc lunch and coffee breaks)	In depth sessions with leading experts covering: • Principles of microwave-heating technology • Advanced microwave measurements • Multiphysics modelling • Applicator design and configurations	Introduction to basic concepts and techniques of computer modelling for microwave power systems and processes, including: • Lectures on fundamentals of FEM and FDTD in COMSOL Multiphysics and QuickWave. • Important case studies, with examples of successful modelling projects. • Hands on sessions with step by step modelling in COMSOL Multiphysics® and QuickWave.
6pm-8pm	Registration and drinks at the conference venue	

Tuesday 12th September

	Main auditorium		
08:45	Opening AMPERE 2023 and Plenary sessions I		
11:00	Coffee break		
	Room 1	Room 2	Room 3
11:30	Chemistry/biochemistry and applications I	Biomass and waste processing I	Energy and environmental applications I
12:45	Lunch		
13:45	Poster session		
14:45	Chemistry/biochemistry and applications II	Biomass and waste processing II	Energy and environmental applications II
16:00	Coffee break		
16:45	Chemistry/biochemistry and applications II	Plasma phenomena and processing I	Energy and environmental applications II
18:00	Close		
19:00	Drinks reception at the Coal Exchange		

Wednesday 13th September

	Main auditorium		
09:00	Plenary and keynote sessions II		
11:00	Coffee break		
	Room 1	**Room 2**	**Room 3**
11:30	Industry focus I	Industry focus II	Industry focus III
12:45	Lunch		
13:45	Panel discussion		
14:30	Plasma phenomena and processing II	Industrial equipment and scale up	Materials properties and interaction I
15:45	Coffee break		
16:15	Plasma phenomena and processing III	Food processing & process intensification	Materials properties and interaction II
17:30	**Close**		
19:45	**Gala dinner at the National Museum of Wales**		

Thursday 14th September

	Main auditorium		
09:00	Plenary and keynote sessions III		
11:00	Coffee break		
	Room 1	**Room 2**	**Room 3**
11:30	THz mm-wave and solid state technology	Modelling and numerical techniques	Materials properties and interaction III
12:45	Lunch		
13:45	Medical and biological applications	Design of applicators and components	Measurements and metrology
15:00	Coffee break		
	Main auditorium		
15:30	Ampere OGA		
16:15	Closing Ceremony		
16:45	**Close**		

About AMPERE Newsletter

AMPERE Newsletter is published by AMPERE, a European non-profit association devoted to the promotion of microwave and RF heating techniques for research and industrial applications (http://www.ampereeurope.org).

Call for Papers

AMPERE Newsletter welcomes submissions of articles, briefs and news on topics of interest for the RF-and-microwave heating community worldwide, including:

- Research briefs and discovery reports.
- Review articles on R&D trends and thematic issues.
- Technology-transfer and commercialization.
- Safety, RFI, and regulatory aspects.
- Technological and market forecasts.
- Comments, views, and visions.
- Interviews with leading innovators and experts.
- New projects, openings and hiring opportunities.
- Tutorials and technical notes.
- Social, cultural and historical aspects.
- Economical and practical considerations.
- Upcoming events, new books and papers.

AMPERE Newsletter is an ISSN registered periodical publication hence its articles are citable as references. However, the Newsletter's publication criteria may differ from that of common scientific Journals by its acceptance (and even encouragement) of news in more premature stages of on-going efforts.

We believe that this seemingly less-rigorous editorial approach is essential in order to accelerate the circulation of ideas, discoveries, and contemporary studies among the AMPERE community worldwide. It may hopefully enrich our common knowledge and hence exciting new ideas, findings and developments.

Please send your submission (or any question, comment or suggestion in this regard) to the Editor in Chief in the e-mail address below.

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