INTERNATIONAL ELMECO – 10 CONFERENCE

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Review of Plasma Technologies for Agriculture, Biomedicine, Energy and Environment

A G E N D A

- Introduction - cooperation history
- Why plasma technologies are so universal?
- Review of research in energy, environment, agriculture and biomedicine
- Milestones of our research on plasma tech
- International and National research projects
- Conclusions

INTRODUCTION

- 42 years ago, in 1979, Electrical Engineering Faculty of LUT started cooperation with Kanazawa University - prof. Kazuo Bessho, in 1982 Andrzej Nafalski start his 2.5 year postdoc, in 1985 LUT sign the cooperation agreement;
- 40 years ago our department started research in the area of plasma and superconductivity application;
- 20th anniversary of the establishment of the CoE under the 5th Framework Program of the European Union (2002-2006) „Application of Superconductivity and Plasma Technology in Power Engineering" ASPPECT;
- 10th ELMECO conference – in 2024 30 anniversary of the first ELMECO in 1994

Why plasma technologies are so universal?

Main reason of plasma applications is the ability to freely control plasma parameters within wide limits, depending on the application, through:

- chemical composition of the working gas, which determines the type and energy of active plasma particles
- pressure - ranging from near vacuum to atmospheric;
- structure of the electromagnetic field; an externally excited electric and / or magnetic field is used to accelerate, heat, compress and direct plasma particles;
- discharge geometry - lack or presence of electrodes and dielectric, volume of the discharge space;
- parameters of the supply system (power, voltage, frequency, number of phases, shape of the supply voltage, internal impedance of the supply system).

Plasma application complexity

Gas (argon, nitrogen, helium, oxygen)

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- Dielectric barrier discharge (Surface, needle)
- Corona discharge
- Other type of discharges

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- Ions(Positive, Negative)
- Free radicals
- Molecules
- Atoms
- Electrons
- Photons

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- **Agriculture** → sterilization, pre-sowing treatment, seed germination
- **Environment** → water, air, soil
- **Food process** → sterilization
- **Medical devices**→ therapy (skin), sterilization, tooth bleaching, implant modification, veterinary therapy

State	O_2
Molecule	O3, O2
Atom	O
Metastable	O
Positive ion	O+ , O2+
Negative ion	O-, O2-, O3-
Free radical	$^{\cdot}O$, $^{\cdot}O_2$
Electron	e
Photon	γ

→

OPTIMUM PLASMA STATE

- Discharge type and material gases
- Total system and operation
- How to treat the objects
- Safety for human health
- Manufacturing and commercial permission (clinical trial, term, cost)
- System cost performance

Research on technological application of AP NTP

- Assessing the suitability and effectiveness of various types of electrical discharges for plasma generation at AP
- Improving the process of generating electrons ions, oxygen and nitrogen radicals useful for water, solid and liquids waste, soil treatment and in biomedicine;
- Achieving the desired composition of the final gas mixture and a high degree of conversion of harmful compounds by adding admixtures and catalysts (steam, ammonia);
- Minimising energy consumption, capital and operating cost;
- Matching the electric power source to the plasma reactor, including solar energy;
- Electromagnetic compatibility of the power supply systems;
- Safety of plasma and plasma equipment for living organism.

Plasma Application for Energy and Environment

Modern energy systems and the natural environment do not develop in a sustainable manner, so as to provide future generations with access to energy that will be generated from renewable sources and will not degrade the natural environment.

- **decomposition of nitrogen and sulfur oxides in flue gases and volatile organic compounds (VOCs) emitted during various industrial processes;**
- **generation of hydrogen H, fuel of the future**
- **conversion of the greenhouse gases (CO_2, C_2H_4) to synthesis gas or liquid fuels and their valorization;**
- **water purification – DBDs in air or oxygen produce oxidizing agents, H*, O*, O_3 and hydrogen peroxide H_2O_2. The strong electric fields of discharges and UV radiation are also lethal to several kinds of microorganisms in water;**
- **removal of hazardous pollutants from waste water, solid waste and biomas combustion.**

Plasma for Agriculture, Food Industry and Pest Control

Soil quality is a crucial factor for the prosperity and future of a region. Agriculture and soil protection include problems related to the overuse of chemicals to fertilise soil, which causes soil degradation; increases pesticide residues in soil, groundwater and food; affects plant cultivation, seed quality and their germination capacity.

- soil treatment – the afterglow of discharges that generate a non-thermal plasma in air or in oxygen is the source of sterilization agents, like ozone, NO, activated oxygen and nitrogen,
- food pasteurization, disinfection and preservation – O_3 is used in common refrigerators as a deodorizing and antimicrobial agent,
- food storage packages sterilization;
- storing of agriculture products – ozone increasing storage life, sanitizing fruit and vegetable surfaces;
- plant growth enhancement and fruit formation processes,
- seed germination.

Plasma for Biomedical Applications

Starting from the 1990s, the development of medical plasma has demonstrated remarkable progress; it was found that the low-temperature plasma (LTP) can be used not only for inactivating pathogens but also for disinfecting biological tissues and, in the long term, for wound healing.

- sterilization of human and animal tissues, blood and surface wounds, skin cancer therapy,
- odontology – caries therapy, coating of implants, contact optical lens, dentures with biocompatible films,
- live tissue engineering – fabrication of bioactive agents and medicines, immobilisation of biological molecules, cell surface modification to control their behavior, improvement of blood adhesion,
- sterilization of medical and surgical instruments, especially made of materials and fabrics not resistant to high temperature,
- medical diagnostics – fabrication biosensors based on polymers and thin amorphous films for medical and bio-chemical analysis.

In our department under the leadership of prof. Pawłat, research in this area is carried out as part of international projects.

Milestones of our research on plasma tech

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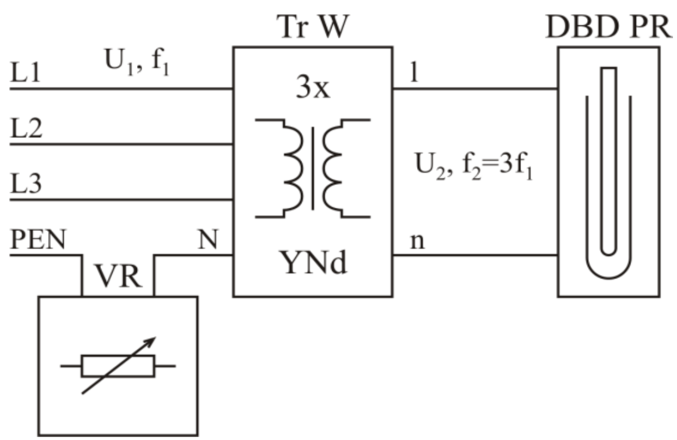
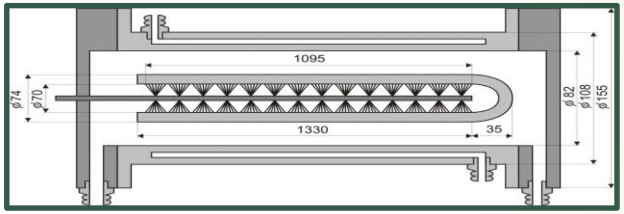
Power system of ozone generator in the mineral water plant in Grodzisk Wielkopolski, Poland (1982-1990) – different solution of the supplier was protected by 3 Polish patents.



An ozone generator consisted of 12 glass discharge pipes 1.2 m long and with external diameter 90 mm with a capacity of 100 g O3 / h)



In the system that had been in operation since 1975, the two-machine rotating frequency converter (f2 = 135 Hz) was replaced with a static magnetic frequency tripler (f2 = 150 Hz).

Features of the supplier include: high efficiency of energy conversion to plasma; higher active power to ozone generator and higher than for inductive loads power factor of the entire system, without the need to use additional elements (compensators). Results of the numerical analysis of this system I presented at the INTERMAG 1987 conference in Tokyo and published in the IEEE Transaction of Magnetics, VOL. MAG-23 NO 5, 1987, pp. 3762-3764.

Milestones of our research on plasm tech

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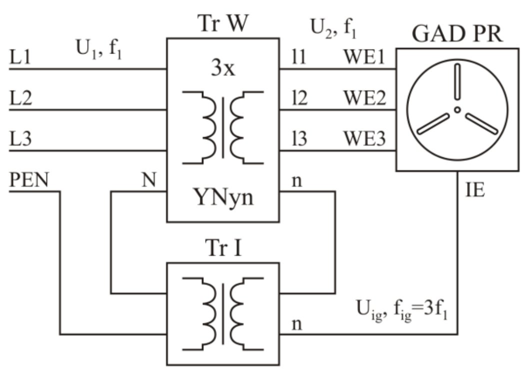
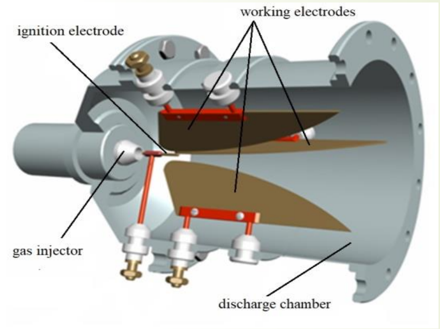
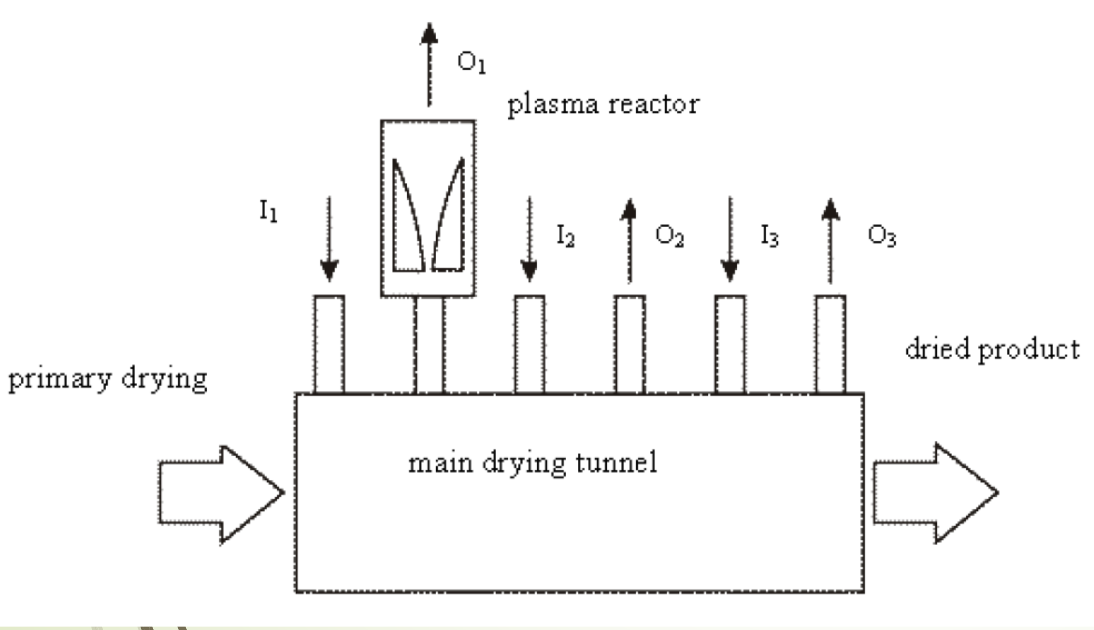
Integrated power system (IPSS) for GAD reactor – cooperation with prof. Albin Czernichowski - inventor of the GAD reactor from Orleans University, France (1991- 2000)







GAD plasma reactor has been applied of the exhaust gas purification from paint shop of the Lublin foundry of machine and truck molds with promising results of VOCs removing.

Milestones of our research on plasm tech 2003 - up to now

Initiated in 1993 by prof. Ebihara and his colleagues from the Department of Electrical and Computer Engineering, Kumamoto University program: Endowed Chair by Kyshyu Electric Power Corporation: on Advanced Technology for Electrical Energy lasted for 12 years (1993-2005) and a total of 22 researchers from around the world were involved in research and education in the area of science and technology.

I am one of these 22 researchers, the only from Poland, among professor from USA, India, Sweden, Rusia, Portugal, Germany and Canada; and one from two women.

It was very important milestone both for LUT collaboration with Japanese universities, resulted in signing cooperation agreements with Kumamoto (2015) and Sojo (2008) universities, participation in common projects, conferences and in many joint publications and for my individual research and development in the area of plasma application for agriculture.

International research projects

In 2010-2022, our department was a coordinator or contractor in 8 international projects:

- Maria Curie Reintegration Grant within 7th Framework Program of EU – PLASMA STERILIZATION 2010 -2014
- ERA-NET scheme: KORANET – ENV-BIO-GA 2012 – 2014
- COST Actions: MP1101 Biomedical Applications of Atmospheric Pressure Plasmas BIOPLASMA 2012-2016
- COST Actions: TD1208 Electrical Discharges with Liquids for Future Applications, 2013 – 2017
- ERA-NET scheme: KONNECT – CatPlas 2016 – 2018
- M-ERA.NET2 Joint Call 2017: PNANO4BONE 2018- 2021
- COST Action: CA20114 Therapeutical applications of Cold Plasmas, PlasTHER 2021-2025
- NAWA, National Agency of Academic Exchange, International Academic Partnerships, POL-JAP ENERGO-ECO 2019- 2022

All of them were devoted to plasma technologies.

NAWA, POL-JAP ENERGO-ECO 2019-2022

IAP

Project partners from Japan:

Kenji Ebihara – EELa, Kumamoto
Fumiaki Mitsugi – KU, Kumamoto
Shin-ichi Aoqui – SU, Kumamoto
Maasaki Yamazato - RU Okinawa
and staff and students

Project partners from LUT:

Staff of EE & Electrot. Department:
H.D.Stryczewska, T.Giżewski, J. Kozieł, O.Boiko, P. Mazurek, R. Jaroszyńska, J. Majcher, G. Komarzyniec, Y. Boiko, L. Jaroszyński, and students

Project tasks and aims:

- study visits and exchange of experts in the field of electrical engineering and ecology at partner universities,
- promoting best practices and innovative solutions in the field of non-thermal plasma generation using Gliding Arc (GA) and dielectric barrier discharges (DBDs) for applications in electrical and ecological engineering, by participating in conferences organized by the project partner;
- defining new and strengthening the existing research disciplines in the field of R&D and in cooperation with the needs of local enterprises;

Project NAWA tasks and aims:

- Strengthening cooperation with KU, SU and EEL and establishing a new one with RU to intensify and develop innovative solutions in the field of R&D;
- Internationalization of education, increasing the competitiveness of university graduates participating in the project on local and international labor markets, promoting the field of electrical engineering among candidates for studies, through visits of students and their tutors in partner universities;
- Preparation of a joint monograph in English on advanced technologies used in energy and environmental engineering and joint publications, the aim of which is to present the results of research of project partners, not only in plasma technologies, but also other modern technologies that serve energy and the environment, and to encourage students and PhD students to undertake research related to these topics.

ADVANCED TECHNOLOGIES FOR ENERGY AND ENVIRONMENT

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Problems of energy and the environment

- depletion of natural energy resources;
- power losses and degradation of energy quality;
- air, water and soil pollution, causing diseases in humans, like asthma, lung, skin, and bacterial and viral diseases.
- hazardous and radioactive waste;
- climate change and global warming;
- electromagnetic smog and noise.

Solving these problems requires interdisciplinary cooperation of researchers from such disciplines as:

Plasma chemistry and physics,
Chemical technology,
Electrical Engineering,
Environmental Engineering,
Material engineering,
Metrology,
Agricultural Engineering,
Bioengineering,
Biochemistry,
Microbiology,
Medicine