ISNTP-10
International Symposium on Non-Thermal/Thermal Plasma Pollution Control Technology and Sustainable Energy.
August, 1-5, 2016, Florianopolis, SC, Brazil.

10th International Symposium on Non-Thermal/Thermal Plasma Pollution Control Technology and Sustainable Energy – ISNTP-10

Scientific Program

&

Book of Abstracts

Florianopolis, SC, Brazil, August 1 a 5, 2016

ISNTP-10
International Symposium on Non-Thermal/Thermal Plasma Pollution Control Technology and Sustainable Energy.
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ISNTP-10, 10th International Symposium on Non-Thermal/Thermal Plasma Pollution Control Technology and Sustainable Energy, Florianopolis, SC, Brazil, August 1 – 5, 2016. Scientific Program and Book of Abstracts.

Edited By Nito A Debacher

2016, UFSC - Imprensa Universitária.
Florianópolis, SC, August 2016.

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ISNTP-10
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Preface

Dear Colleagues,

The 10th International Symposium on Non-Thermal/Thermal Plasma Pollution Control Technology and Sustainable Energy (ISNTP-10) will be held in Florianopolis**,** Brazil, from the 1st to 5th of August 2016.

The ISNTP-10 is sponsored by the International Electrostatic Assembly and is undertaken by the Chemistry Department of the Federal University of Santa Catarina, Brazil. The ISNTP is currently a biannual conference which started in the UK in 1992. Editions were held in Brazil 1997, Korea 2001, USA 2004, France 2006, Taiwan 2008, Canada 2010, France 2012 and China 2014.

Since the first edition, a wide range of environmental applications using non-thermal and thermal plasma technologies was covered: flue gas treatment, water treatment, solid and liquid waste treatments, and more recently fuel reforming and plasma assisted combustion. Emerging topics such as surface bio-decontamination and medical applications appeared in the 2004 edition in USA and Electrostatic appeared in the 2014 edition in China. Besides applications, fundamentals in discharge physics and plasma chemistry are also considered. Specifically, the following topics will be discussed:

Main Topics

Fundamental of Atmospheric Discharge Phenomena
Modeling and Simulation of Atmospheric Discharge
Gas Treatment (acid gas/VOCs & odor/greenhouse gas/PM)
Indoor Gas Cleaning
Water Treatment (waste/ground/drinking)
Hazardous Material Treatment (dioxin /PCB /halogenated compounds /mercury)
Electrostatics
Combination of Plasma with other Technologies (catalysis/biodegradation/adsorption)
Plasma Assisted Combustion
Fabrication of Materials by Plasma
Fuel Reforming & Energy-Related Applications
Plasma Medicine, Biology and Bio-decontamination

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This book collects the abstracts of the scientific reports contributed to ISNTP-10 authored by researchers from all over the world, including 14 keynote lectures, 21 oral presentations and 34 poster presentations. A collection of contributed papers will be also made available to participants in electronic format on USB stick. A selection of contributed papers will be considered for publication in the *International Journal of Plasma Environmental Science and Technology* (*IJPEST*).

We are confident that ISNTP-10 will continue the tradition of successful ISNTP conferences and that it will be a fruitful and challenging experience for us all. We wish you all a pleasant stay in Florianopolis.
With best regards,

Nito A Debacher,
Chair of the ISNTP-10

Florianopolis, August , 2016.

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Committees

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Program, ISNTP-10

Time schedule	Sunday July 31st	Monday August 1st	Tuesday August 2nd	Wednesday August 3rd	Thursday August 4th
9:00 –9:20		Opening Ceremony			
9:20 – 10:00		I-1	I - 6	I - 8	I - 13
10:00 – 10:20		O-1	O - 7	O - 10	O - 16
10:20 – 10:40		O-2	O - 8	O - 11	O - 17
10:40 – 11:00		**Coffee break**	**Coffee break**	**Coffee break**	**Coffee break**
11:00 – 11:40		I - 2	I - 7	I - 9	I - 14
11:40 – 12:00		O-3	O - 9	O - 12	O - 18
12:00 – 14:00		**Lunch**	**Lunch**	**Lunch**	**Lunch**
14:00 – 14:40		I - 3		I - 10	I - 15
14:40 – 15:00		O - 4		O - 13	O - 19
15:00 – 15:20		O - 5		O - 14	O - 20
15:20 – 15:40		O - 6	**Excursion**	O - 15	O - 21
15:40 – 16:00		**Coffee break**		**Coffee break**	Closing Remarks
16:00 – 16:40	**Registration**	I - 4		I - 11	**Coffee break**
16:40 – 17:20		I - 5		I - 12	
17:20 – 17:40					
17:40 – 18:00		Poster		Poster	
18:00 – 18:20		Session		Session	
18:20 – 18:40		(1-17)		(18 – 34)	
18:40 – 19:00	**Welcome**				
19:00 – 19:20					
19:20 – 19:40					
19:40 – 20:00					
20:00		**Dinner**		**Dinner**	

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General information

The 10th International Symposium on Non-Thermal/Thermal Plasma Pollution Control Technology and Sustainable Energy (ISNTP-10) will be held in Florianopolis, Brazil, from the 1st to 5th of August 2016.

Venue and social events

All participants are encouraged to make their reservation at the "Hotel Slaviero Essential Florianopolis Ingleses Acquamar" in Florianopolis, Ingleses beach, Rua das Gaivotas, 1114.

Registration and all scientific activities will be held at the "Hotel Slaviero Essential Florianopolis Ingleses Acquamar" in Florianopolis, Ingleses beach, Rua das Gaivotas, 1114.
Registration will be open on Sunday July 31, from 14:00 to 18:00 and Monday August 1, starting at 8:40.

The registration fee includes:

Shuttles to/from airport; a book of abstracts and a USB-stick containing the full papers; Monday lunch; the welcome dinner; the excursion & conference dinner and coffee breaks. Note that all lunches and dinners except Monday lunch, the welcome and conference dinners will be left to the charge of the participants.

Information for Authors presenting oral and poster contributions

Oral Presentations

Invited Lectures will be 40 min (35 + 5 discussion). Oral presentation will be 20 min (15 + 5 discussion). The lecture hall is equipped with a Windows PC. Supported presentation formats are Microsoft Power Point and PDF. Please be prepared to have your presentation ready on a portable USB-stick (pen drive).
If you prefer to use your own computer, please inform in advance the conference staff.

Poster presentations

Poster size: The posting boards are 140 cm (width) x 100 cm (height). Within these limits, Authors are free to choose their poster size and format.
You will find your poster number attached to the poster wall.
The poster should be posted in the day of the presentation and must be removed the day before the following poster session.

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Registration and all scientific activities will be take place at the Conference hotel, "Slaviero Essential Florianopolis Ingleses Acquamar Hotel" in Florianopolis, Ingleses beach, Rua das Gaivotas, 1114.

(**I**) Stands for invited lecture (40 min); (**O**) Stands for Oral communications (20 min); (**P**) Stands for Poster communications (120 min).

July 31, 2016, Sunday

14:00 – 18:00	Registration
18:00 – 20:00	Welcome

August 1, 2016, Monday

Chair: A. **Mizuno**

8:40 – 9:00	Registration
9:00 – 9:20	Opening Ceremony
9:20 – 10:00	Invitation Letter, **I - 1** F. Fracassi - University of Bari, Italy, Functional materials for environmental applications prepared by atmospheric pressure cold plasma
10:00 – 10:20	**O – 1**, T. Butterworth Impact of packing material on plasma behavior in a catalyst packed DBD for CO_2 and biogas conversion
10:20 – 10:40	**O – 2**, J. C., Sagaz Simulation of metal transport in grid assisted magnetron sputtering

10:40 – 11:00	**Coffee Break**

Chair: F. **Fracassi**

11:00 – 11:40	Invitation Letter, **I - 2** A. Mizuno, Toyohashi University of Technology, Japan. Induction charging of fine particles and low temperature plasma process for gas cleaning
11:40 – 12:00	**O – 3**, H. Sato Ozone generation by nanoseconds pulsed discharge in compressed air

12:00 – 14:00	**Lunch**

Chair: K. **Urashima**

14:00 – 14:40	Invitation Letter, **I – 3;** J. C. Sagaz, CCT-UDESC Joinville, SC, Brazil Plasma assisted combustion of natural gas using gliding arc discharge
14:40 – 15:00	**O – 4**, M. Ramakers CO_2 conversion in a gliding arc plasmatron.
15:00 – 15:20	**O – 5**, M Schmitd see abstract **O-10** Combined electric wind and non-thermal plasma for gas cleaning
15:20 – 15:40	**O – 6**, R. Snoeckx Unwanted NOx production during the conversion of CO2 in a dielectric barrier discharge in the presence of N2 and how to prevent it

15:40 – 16:00	**Coffee Break**

Chair: **A.G. Cunha**

16:00 – 16:40	Invitation Letter, **I – 3; see I-4** K. Urashima, National Institute of Science and Technology policy (NISTEP), Japan. Trends in indoor air cleaning with technology and market.
16:40 – 17:20	Invitation Letter, **I – 5** A. G. Cunha, Thermal plasma Lab., Federal University of Espirito Santo, ES, Brazil. Reforming of compressed natural gas using intermediate and thermal plasmas with gases like argon, nitrogen, hydrogen and carbon dioxide.

Poster Session I

17:20 – 19:00	**Poster Session 1 – Posters P – 1 to P – 17**
	P-1, Pericles I. Khalaf Kinetic Study of Paraquat Degradation in Aqueous Media by a Corona Air Plasma System.
	P-2, Yao Wuang CO_2 Hydrogenation in a non-thermal plasma aided by supported metal catalysts.
	P-3, Tomoaki Miichi Discharge products measurement in a DC corona discharge over water by IR spectroscopy.
	P-4, Thiago Voigdlener Magneto Hydro Dynamics Modeling of DC Thermal Plasma Torch.

	P-5, Serge Alain Djepang Evidence of the presence and reactivity of long life species in gliding arc plasma: Spatial and Temporal Post-Discharge reactions.
	P-6, Diego A Duarte Effect of the reactive gas mixture on electrical properties of TiO_2 thin films deposited by grid-assisted magnetron sputtering.
	P-7, Ramses Snoeckx Non-Equilibrium Gliding Arc and Dielectric Barrier Discharge Treatment of Liquids for Pathogen Removal from Food and Food-Contacting Surface.
	P-8, Moise Fouodjouo. Synthesis of tungsten oxide nanorods using non-thermal plasma at atmospheric pressure.
	P-9, Maria Elisa Philippsen TiO_2 film on glass substrates: The effect of coat thickness on photocatalytic activity.
	P-10, Kazimierz Adamiak Formation and the impact of photoionization on the Trichel pulses in air.
	P-11, Karen Castro Multi-step Mechanism of Graphite Ozonization.
	P-12, Julio César Sagás Simulation of metal transport in grid assisted magnetron sputtering system.
	P-13, Cézar A. de A. Arpini Synthesis of graphitic carbon by thermal plasma decomposition of methane.
	P-14, Bruno Mena Cadorin Influence of pH and buffer composition on the degradation of methyl orange azo dye by spark discharge non-thermal plasma: byproducts analysis.
	P-15, Armando José Pinto Simulation of the fluid dynamics in a swirl-stabilized and plasma assisted burner.
	P-16, Anna Paula S. Crema The influence of hydrogen peroxide in the discoloration reaction of the dyes red phenol and indigo carmine employing a non thermal plasma reactor .
	P-17, Felipe Antonio Cassini The AC rotating gliding arc applied in the propane pyrolysis for gas phase synthesis of CB.

20:00	**Dinner**

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August 2, 2016, Tuesday

Chair: C. Paradisi

9:20 – 10:00	Invitation Letter, **I - 6** E. Marotta, University of Padova, Padova, Italy Comparison of the degradation mechanisms of organic pollutants in water in a reactor powered by positive DC, negative DC and DBD.
10:00 – 10:20	**O – 7**, S. Kodama Persistent Organic Pollutants Treatment in Wastewater using Nano-Seconds Pulsed Non-Thermal plasma
10:20 – 10:40	**O – 8**, L.O.B. Benetoli Acid/Base Catalysis of Phenol Degradation by Non-Thermal Plasma Discharge

10:40 – 11:00	**Coffee Break**

Chair: E. Marotta

11:00 – 11:40	Invitation Letter, **I - 7** C. Paradisi, University of Padova, Padova, Italy Efficiency of mineralization, mechanisms and intermediates of plasma induced advanced oxidation of emerging organic contaminants in water.
11:40 – 12:00	**O – 9**, S. Sério Nanocrystalline TiO_2 –WO_3 bilayered films produced by reactive sputtering for photocatalytic applications

12:00 – 13:30	**Lunch**

13:30 – 18:30	**Excursion**

August 3, 2016, Wednesday

Chair: M. B. Chang,

9:20 – 10:00	Invitation Letter, **I - 8** X. Tu, Electronics, University of Liverpool, Liverpool, UK Plasma-catalysis for energy and environmental applications.
10:00 – 10:20	**O – 10**, A Cubas, see P-32

	Thermal Plasma Application for Treatment of Sludge Leachate.
10:20 – 10:40	**O – 11**, H. L. Chack Electro-hydrodynamically Enhanced Non-thermal Plasmas: Filtration and Inactivation of Airborne Infectious Aerosols

10:40 – 11:00	Coffee Break

Chair: X. Tu

11:00 – 11:40	Invitation Letter, **I - 9** M. B. Chang, National Central University, Taiwan. Application of non-thermal plasma and perovskite-type catalyst for gaseous pollutant removal and syngas generation.
11:40 – 12:00	**O – 12**, C.Soares; see abstract O-20 Multi-Step Modeling of a Rotating Gliding Arc (RGA) Reactor

12:00 – 14:00	**Lunch**

Chair: H. Maciel

14:00 – 14:40	Invitation Letter**, I - 10** G. Harvel, University of Ontario Institute of Technology, Canada Recovery of Radioactive Iodine from Nuclear Power Plants using a Microwave Based Plasma Technique
14:40 – 15:00	**O – 13**, T. Kawasaki Detection of reactive oxygen species transported into liquid bottom by atmospheric non-thermal plasma jet
15:00 – 15:20	**O – 14**, M. M. Machado Spent Batteries Final Treatment using Thermal Plasma
15:20 – 15:40	**O – 15**, A. Mizuno Analysis of dominant effect caused by plasma irradiation on inactivation of viruses

15:40 – 16:00	**Coffee Break**

Chair: G. Harvel

16:00 – 16:40	Invitation Letter, **I - 11**

	H. Maciel, Institute for Research and Development – IP&D – UNIVAP, SP, Brazil. Demonstration of thermal plasma system for solid waste vitrification and WTE applications
16:40 – 17:20	Invitation Letter, **I - 12** A.Smaniotto, Chemistry Department, Federal University of Santa Catarina, Brazil Non-thermal plasma treatment of graphene oxide sheets for selective insertion of sulfur dioxide reduction intermediates.

Poster Session II

17:20 – 19:00	**Poster Session II – Posters P – 18 to P – 34**
	P-18, Xin Tu Plasma-catalytic reforming of biogas into value-added fuels
	P-19, Ramses Snoeckx How does N2 influence the dry reforming of methane in a dielectric barrier discharge: a combined experimental and computational study
	P-20, Rafael B Recco Acid/Base Catalysis of Phenol Degradation by Non-Thermal Plasma Discharge
	P-21, Natália Medeiros Synthesis of high purity silicon carbide by non transferred arc thermal plasma
	P-22, Moise Fouodjouo Coupling of non-thermal plasma and biosorption onto *Baillonella Toxisperma* for the disposal of Red_Remazol B in water
	P-23, Lucas Machado The DBD plasma applied to control liquid transport for µPADs
	P-24, Julio César Sagás Temperature effect on the formation of Ti_2O_3 in magnetron sputter deposition
	P-25, Joel Stryhalski Niobium doped titanium oxide thin films: optical transparent and electrical conductive oxide (TCO)
	P-26, Gabriela Prieto Selective Hydrogen Production by Non Thermal Plasma Processing of Residual Heavy Oil
	P-27, Gilberto Petraconi Mercury Removal From Solid Waste By Reactive Plasma And Thermal Disorption

	Processes
	P-28, Edson Luis Guinter Polymerization of maleic anhydride films assisted by plasma
	P-29, Cézar A. de A. Arpini Decomposition of dichloromethane by dielectric barrier discharge non thermal plasma reactor
	P-30, Cristiane Mezaroba Plasma sterilization of HDPE polymer through N_2-O_2 RF discharge
	P-31, Carolina dos Santos Cardoso Polysort functionalization of LDPE by exposition on medium pressure treatment of DBD non thermal plasma
	P-32, Anelise L Vieira Cubas Thermal plasma application for treatment of sludge leachate.
	P-33, Susana Sério Monosort functionalization and derivatization of polypropylene surface by non thermal plasma
	P-34, Kazunori Takashima Analysis of dominant effect caused by plasma irradiation on inactivation of viruses
	P-35, Patricia Souza Flipe Methylene blue degradation by non-thermal plasma in the presence of sulphide minerals: primary insights about homogeneous and heterogeneous catalysis

20:00	**Dinner**

August 4, 2016, Thursday

Chair: G. Touchard

9:20 – 10:00	Invitation Letter, **I - 13** H-H. Kim, National Institute of Advanced Industrial Science and Technology (AIST) Japan Plasma-Catalysis: From Catalyst Screening to Gas Cleaning Process
10:00 – 10:20	**O – 16**, X. Tu; see O-20 Plasma gas cleaning process for the removal of model tar from biomass gasification
10:20 – 10:40	**O – 17**, K. Van Wesenbeeck Mineralisation of ethylene by plasma catalysis

10:40 – 11:00	**Coffee Break**

Chair: H-H. Kim

11:00 – 11:40	Invitation Letter, **I - 14** G. Touchard, Prime Institute, Boulevard Marie & Pierre CURIE, France Plasma actuators and flow control.
11:40 – 12:00	**Canceled**

12:00 – 14:00	**Lunch**

Chair: A. Mizuno

14:00 – 14:40	Invitation Letter, **I - 15** L. C. Fontana, Plasma Laboratory, UDESC, Joinville, SC, Brazil The major contribution of low-temperature plasma to surface science and technology

14:40 – 15:00	**Closing Remarks**

15:00 – 15:20	**Coffee Break**

Invited lectures

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Functional materials for environmental applications prepared by atmospheric pressure cold plasma

I-1

Fracassi F

[1]*Department of Chemistry, University of Bari "Aldo Moro", via Orabona 4, 70126 Bari, Italy* [2]*Institute of Nanotechnology, National Research Council, c/o Department of Chemistry, University of Bari "Aldo Moro", via Orabona 4, 70126 Bari, Italy*

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Water pollution is one of the most urgent and complex environmental problems. For instance, purification systems for wastewater have to face a complex mixture of various pollutants that, besides immiscible hydrophobic organic species, can include also several water-soluble pollutants, such as heavy metals and organic compounds (e.g., dyes, surfactants, halogenated compounds, etc.). Therefore, over the last years, through rational design of surface structure and chemical composition, more and more functional materials have been fabricated and developed for water purification [1].

In this contribution our recent studies on surface processing of materials by atmospheric pressure dielectric barrier discharges (DBDs) are presented with particular focus on the preparation of functional materials for water remediation. The examples presented will include: i) the preparation of superhydrophobic/superoleophilic membranes and sponges for oil/water separation by filtration and absorption, respectively [2, 3]; ii) the photocatalytic activity of plasma-deposited coatings containing ZnO nanoparticles for the degradation of organic pollutants in water [4]; iii) preliminary results on atmospheric pressure plasma processes for the preparation of materials characterized by surface functional groups that can play an important role in the adsorption and removal of heavy metals from water [5].

[1] R. Li, L. Zhang, and P. Wang, *Nanoscale*, 7, 17167 (2015).

[2] F. Fanelli, A. M. Mastrangelo, and F. Fracassi, *Langmuir*, 30, 857 (2014).

[3] F. Fanelli and F. Fracassi, *Plasma Processes and Polymers,* DOI: 10.1002/ppap.201500150 (2015).

[4] F. Fanelli, F. Mastrangelo, N. De Vietro, and F. Fracassi*, Nanoscience and Nanotechnology Letters*, 7, 84 (2015).

[5] P. Bosso, F. Fanelli, and F. Fracassi, *Plasma Processes and Polymers,* DOI: 10.1002/ppap.201500005 (2015).

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Induction charging of fine particles and low temperature plasma process for gas cleaning

I-2

Akira Mizuno

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Electrostatic precipitation is an old but useful technique of applied electrostatics to control fine particles. In order to decrease energy consumption, induction charging is an alternative to conventional corona charging. Possibility of the use of induction charging in ESPs are discussed. Performance of a filter can be improved when suspended particles are charged prior to the filter. Induction charging or corona charging can be used for this purpose. For collection of PM (particulate matter) in diesel engine exhaust, an experiment was conducted to use corona charging prior to a DPF (diesel particulate filter made of ceramics). The collection performance can be improved significantly. After collecting PM, a discharge inside the DPF was generated for regeneration (or to oxidize collected PM) of the DPF at low temperature condition of less than 200 degree C. This discharge can be used to oxidize NO at low temperature condition. This feature can be used to improve the deNOx efficiency at low gas temperature condition such as idling or cold start. In addition, the on board ammonia production process is discussed for deNOx of vehicle emission using non-thermal plasma chemical process.

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PM10 and PM2.5 Emission Control from Coal-fried Boilers with Modern Electrostatic Precipitators

I-3

Yan K

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Modern dry electrostatic precipitators (ESPs) for coal-fired power plants can be applied either below or above SO_3 acid dew point, which have been called coder-side and normal ESPs. Traditional equipped high-voltage (HV) power source is single-phase transformer rectifiers (T/R). Modern ESPs are usually equipped with three-phase T/R, or switch mode power sources or pulse one. For example, one recent 1000MW coal-fired power plant usually is usually equipped with a ESP with six channels and five electrical fields and 30 HV sources.

With regard to PM10 and PM2.5 emission control (particles with diameters of less than 10 μm and 2.5μm, respectively), we found they mainly depends on corona current density. From the inlet to outlet ESP fields, the current density per unit collection electrodes are normally from 0.4mA/m^2 down to 0.1 mA/m^2, their concentrations are usually below 15mg/m3 and 2.5 mg/m3, respectively.

Over the past three years, we evaluated more than 100 Chinese ESPs, and we can conclude the following: 1) a proper ESP can control the ratio of PM2.5 over PM10 of around 6%-17%. A poor ESP can lead the ratio up to 56%. 2) it is now become common to control PM concentration at the outlet of below 10mg/m^3 and PM2.5 of below 1.0mg/m^3.

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Trends in indoor air cleaning with technology and market.

It covers regulation, technology and market.

I-4

K. **Urashima**

Science and Technology Foresight Centre

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Reforming of compressed natural gas using intermediate and thermal plasmas with gases like argon, nitrogen, hydrogen and carbon dioxide

I-5

Cunha AG

Universidade Federal do Espírito Santo, Departamento de Física, Laboratório de Plasma Térmico, Vitória ES, Brazil

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For 14 years we have developed plasma torches to be used in reforming and pyrolysis of compressed natural gas (CNG) testing various types of gases such as argon, nitrogen, hydrogen and carbon dioxide and using intermediate plasmas or thermal plasmas. Among the intermediate plasmas studied, the tornado configuration showed the best result. In this case, the conversion of CNG was limited to 23%, because an increase of the CNG/CO_2 ratio produces more carbon, causing short circuit between the electrodes. The energetic efficiency in the hydrogen production was similar to that of the thermal plasma torch, but the conversion of CO_2 was very small, leaving the final product with excess of CO_2. The thermal plasmas showed the best results, but with different characteristics for each gas. Argon and nitrogen plasmas produced a good conversion of CNG, but the gas plasma need to be removed at the end of the process. Moreover, nitrogen can produce compounds of the NOx type, which are undesirable. The use of hydrogen plasma showed low performance in the breaking of CNG due its low density. The best results were obtained with a CO_2 plasma. To reach the ideal condition of the anodes, we tested several models with different diameters and lengths, which allowed us to obtain values of energy efficiency (10.8 mol_{H2}/kW or 14 mol (H_2 + CO + C_2H_2)/kW.h) higher than those previously reported obtained for similar torches (TAO et al 2008, 2011;. KHALAF et al 2011). One reason for this was the use of CO_2 as the working gas, injected directly into the cathode, which avoids the need to use an inert gas flow to protect the cathode, when using tungsten. Moreover, the procedure used was more effective for the breaking of the CO_2 molecule, making it more reactive.

[1] TAO, X.; QI, F.; YIN, Y.; DAI, X., *International Journal of Hydrogen Energy*, v.33, p. 1262-1265 (2008).

[2] TAO, X.; BAI, M.; LI, X.; LONG, H.; SHANG, S.; YIN, Y.; DAI, X., *Progress in Energy and Combustion Science*, v. 37, p. 113-124 (2011).

[3] KHALAF, P. I.; SOUZA, I. G. de; CARASEK, E.; DEBACHER, N. A., *Química Nova*, vol. 34, n. 9, p. 1491-1495 (2011).

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Comparison of the degradation mechanisms of organic pollutants in water in a reactor powered by positive DC, negative DC and DBD

I-6

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The application of non thermal plasma to water treatment is particularly attractive due to the possibility of exploiting both UV radiation and reactive oxygen species without the addition of chemicals or the use of UV lamps. In non thermal plasma based systems the decomposition efficiency of a given organic pollutant, the products formed in the treatment and the mineralization degree obtained depend on many parameters, such as the type of discharge, the reactor configuration, the input energy, the duration of the treatment, the composition of the aqueous solution [1,2]. In order to selectively address and evaluate the effect of different discharge regimes, a new prototype plasma reactor was recently developed in our laboratory. It can be powered with DC voltage of either polarity or with dielectric barrier discharges to produce air plasma above water in a controlled environment. The active electrode is an array of seven connected parallel wires fixed to the reactor top and kept at a short distance from the surface of the water to be treated. As for the bottom part of the reactor, which contains the water to be treated, two different interchangeable units have been built: one is lined internally with an inox steel plate connected to ground for DC voltage application, the second is painted externally with colloidal silver and connected to ground for AC voltage application. Synthetic air (a mixture of pure N_2 (80%)/O_2 (20%)) saturated with humidity is flown through the reactor at the desired rate. Ultra pure water was used as reference to determine the concentration of ozone, hydroxyl radical and hydrogen peroxide in the liquid phase, as well as solvent to prepare the solutions of the organic compounds studied as model pollutants. The decomposition process was monitored by HPLC/UV, LC-ESI-MS, Ion Chromatography and TOC analyses of the liquid phase and FT-IR analysis of the gas phase.

The comparison of the results obtained under the different discharge regimes allowed us to identify the main reactive species responsible for the decomposition of the model organic pollutants.

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Efficiency of mineralization, mechanisms and intermediates of plasma induced advanced oxidation of emerging organic contaminants in water

I-7

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There is an urgent need to improve water treatment processes so as to achieve the mineralization, or at least the degradation into non-toxic biodegradable products, of emerging organic contaminants. These include, among others, many pharmaceuticals, products for personal care, perfluorinated compounds, benzotriazoles, and are usually very resistant towards oxidation [1]. We are studying advanced oxidation processes induced by non thermal plasma generated by discharges in air above the contaminated water and are testing and comparing different types of discharges [2]. The lecture will focus on a few study cases dealing with important members of the wide family of emerging organic contaminants including some drugs for humans and animals (verapamil, a phenylalkylamine calcium channel blocker used to treat cardiovascular disorders; carbamazepine, an antiepilectic; atenolol, a beta-blocker; hydrochlorothiazide, a diuretic; amoxicillin, an d, sulfamethoxazole, two antibiotics), pesticides (glyphosate and irgarol), compounds used in cosmetics and in products for personal care (parabenes) and ionic surfactants (PFAs). Different analytical instrumentation and procedures, including LC-MS/MS, Ion Chromatography, TOC and FT-IR, and mechanistic probes are used to carry out kinetic and comprehensive product studies on these processes. Data on the efficiency of mineralization and on the oxidation intermediates and mechanisms will be reported and critically discussed.

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Plasma-catalysis for energy and environmental applications

I-8

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The rapid exhaustion of fossil fuel reserves and the adverse effects of climate change caused by increasing global energy demands have attracted great attention and pose serious threats to humankind. The emergence of new energy technologies is very crucial and essential to reduce the negative effects of climate change and to ensure global energy security based on sustainable and renewable energy sources.

Recently, the combination of non-thermal plasma and heterogeneous catalysis (known as plasma-catalysis) has been regarded as a promising and effective solution for the conversion of carbon emissions (e.g. CH_4 and CO_2) into value-added fuels and chemicals (e.g. H_2, syngas and methanol) at low temperatures [1]. The combination of plasma and catalysts has the great potential to generate a synergistic effect, which can activate catalysts at low temperatures and improve the activity and stability of the catalysts, resulting in the remarkable enhancement of reactant conversion, selectivity and yield of end-products, as well as the energy efficiency of the process [2]. The idea of plasma-catalysis has also been extended to the synthesis, preparation and modification of catalysts to improve the activity and stability of the catalyst.

We have developed different plasma sources (dielectric barrier discharge and gliding arc) for a diverse range of energy applications including the conversion of CH_4 and CO_2 into value-added fuels and chemicals and removal of tars from biomass gasification [1-4]. The integration of plasma and supported metal catalysts clearly exhibits a significant synergistic effect, showing both the conversion of reactants and the yield of target products are significantly enhanced compared to the reaction using plasma alone or catalysis alone.

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Application of non-thermal plasma and perovskite-type catalyst for gaseous pollutant removal and syngas generation

I-9

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Perovskite-type catalysts, with the general structure of ABO3 or A2BO4, have the characteristics of high thermal stability and oxygen exchange activity, thus, packing perovskite-type catalyst into non-thermal plasma reactor may induce synergistic effects. In our laboratory, various perovskite-type catalysts have been integrated with non-thermal plasmas to form plasma catalysis system for several applications, the first is dedicated for NOx abatement, the second is devoted for VOCs removal and the third is developed for dry reforming of CH4 with CO2 to generate syngas.

For NOx abatement, perovskite-type catalyst (SrKMn0.8Co0.2O4) supported on BaO/Al2O3 is packed into dielectric barrier discharge (DBD) reactor for NOx storage and reduction (NSR) process. Perovskite-type catalyst shows a good adsorption capacity, and the NOx reduction rate achieved with DBD is higher than 80% with the operating parameters of applied voltage = 12 kV, frequency = 6,000 Hz and Ar as working gas.

For VOCs removal, La0.8Sr0.2Mn0.8Cu0.2O3 is combined with DBD for oxidizing gaseous phenol into CO2 and H2O(g). Experimental results indicate that phenol removal efficiency and mineralization rate achieved with DBD (without catalyst) are 25% and 4%, respectively, with the operating parameters of applied voltage = 13 kV, frequency = 8,000 Hz, [C6H5OH] = 121 ppm and flow rate = 300 mL/min. As perovskite-type catalyst is packed into DBD reactor, the phenol removal efficiency and mineralization rate are greatly increased to 99.9% and 45%, respectively, under the same operating condition.

Perovskite-type catalyst may own unique electric properties such as ferroelectricity. Ferroelectric (BaZr0.05Ti0.95O3) is combined with spark discharge reactor to convert CH4 and CO2 into syngas. Without ferroelectric, CH4 and CO2 conversion efficiencies achieved with spark discharge reach 52.5% and 49.4%, respectively, with the operating condition of applied voltage = 16 kV, frequency = 20,000 Hz, CH4/CO2 = 1 and flow rate = 200 mL/min and the energy efficiency achieved is 13.5 mol/kWh. As ferroelectric is packed into the reactor to form plasma catalysis system, CH4 and CO2 conversions are greatly increased to 84.2% and 79.0%, respectively, and the energy efficiency is also increased to 16.5 mol/kWh, indicating that synergistic effect exists between spark discharge reactor and ferroelectric for syngas generation. Detailed mechanisms regarding NOx removal, VOC removal and syngas generation achieved with plasma catalysis and possible synergistic effects will be elucidated in this presentation.

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Recovery of Radioactive Iodine from Nuclear Power Plants using a Microwave Based Plasma Technique

I-10

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In the event of a nuclear plant accident where the nuclear fuel has been damaged, radioactive Iodine gaseous species can be released into the nuclear plant environment. The containment systems are designed to capture most of the Iodine species and maintain the radiation within the facility. It is possible that in some severe accident scenarios, the containment systems may also fail and the iodine may be released outside the plant. Iodine is known to migrate well in both gas and liquid phases. Thus it is possible for the Iodine to enter the cooling water exiting the plant and from there enter into the ocean plants nearby such as seaweed and kelp. Knowledge of the amount of Iodine present could be obtained from radiation surveys and standard chemical techniques. However, extracting the Iodine in a controlled manner to recover it and remediate the environment would require a more rigorous process.

In this work, a microwave generated plasma is used to elevate the energy of the Iodine molecules found in kelp to the point where ionization can occur. An Argon gas based microwave generated plasma is used as the ionization chamber. The characteristics of the plasma and the iodine species is observed. Different forms of iodine (gas, liquid, solid) are released from the plasma zone downstream of the microwave chamber. The released gaseous species are capture in a filter system and the characteristics of the Iodine species are identified.

The results indicate that I_2, I^- and I^{3-} species are observed. The technique works well at ionizing the Iodine species at relatively low powers and allowing them to be captured by a standard cotton filter. These results suggest that a microwave based technique may be useful for environmental cleanup activities of radioactive species such as Iodine. The technique can be used to address contaminated material as well as treat the gas phase environment.

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Demonstration of thermal plasma system for solid waste vitrification and WTE applications

I-11

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Industrial waste treatment and power generation from alternative sources are very important subjects in the world, especially based on use of the new technologies, including thermal plasma ones. These processes are considered to have good perspectives for waste destroy/inertization and Waste-to-Energy (WTE) applications. Thermal plasma treatment has been under development for many years for the vitrifying combustion residues such as various ashes, in particular for MSW incinerator' residues. In our study new multipurpose plasma reactor and assisted equipment were developed for operation not only in ash waste vitrifying regime, but also in regime of combined vitrifying and gasification of the organic-ash wastes (including typical for Brazilian MSW incineration facilities) to improve total energy efficiency of plasma system with the reactor. Theoretically estimated value of net electricity efficiency (NEE) of specially analyzed combined cycles (based on use of modern gas turbines) with MSW or other solid feedstock, which can be realized in the variants with air or other oxidative gasifying agents, was found to be up to 35-36 %. For optimized design of thermal plasma system with waste feedstock new non-transferred arc plasma torch with reverse gas vortex ("Tornado" type) was designed and analyzed in some details, based on experimental methods and on the physical and analytical modeling with generalization of arc discharge characteristics. This new torch variant has hybrid type cathode, which is the combination of button-type Hf-insertion and well-type copper one. The torch was found to provide high plasma jet enthalpy and thermal efficiency and can be operated with various plasma gases (air, CO_2, air+C_XH_Y) in a combination with advanced 200 kW power supply, which was designed initially for operation with new DC transferred arc torch (twin torch type). Based on these technologies a plasma reactor for combined gasification/vitrifying processing (capacity up to 100 kg/h) has been manufactured and tested for wide ranges of operating parameters. Experimental demonstration of waste processing was made by setting up a pilot unit of solid waste vitrification. Ashes derived from incineration of biomass were the feedstock used for a preliminary evaluation of the vitrification process.

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Non-thermal plasma treatment of graphene oxide sheets for selective insertion of sulfur dioxide reduction intermediates

I-12

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The oxidation of graphite microparticles by strong acids followed by thermal exfoliation resulted in graphene oxide sheets (MPGO). Graphene oxide was treated with non-thermal plasma in a dielectric barrier discharge (DBD) plasma bolt-type reactor under SO_2 atmosphere. The XPS spectrum showed that SO_2 was inserted exclusively as oxidized intermediates shown at 168.7 eV in the S2p region. Short thermal shocks at 600 and 400 ^oC, under Ar atmosphere, produced reduced sulfur and carbon dioxide as shown by XPS spectrum and TGA analysis coupled to FTIR [1]. Refluxing this material in CS_2 (46 ^oC) showed sulfur elimination and interconversion of the oxidized into non-oxidized intermediate without decarboxylation [2]. Thermal modification of graphene oxide with SO_2 at 630 ^oC produced insertion of the non-oxidized intermediate only, as shown by the XPS spectrum in the S2p region at 164.0 eV. Plasma and thermal treatment produced partial reduction of MPGO [1,2]. The sequence of thermal reaction followed by plasma treatment inserted both sulfur intermediates. These results support the hypothesis that there are two major routes with different energetic demand in the sulfur dioxide reduction on carbons: desulfurization and decarboxylation [2]. Since oxidized and non-oxidized intermediates have different reactivities, this selective insertion would allow the functionalization of the surface of graphene oxide with different types of organic fragments [1]. The selectivity of thiolysis and aminolysis toward the intermediates inserted in the MPGO matrix [3] allowed the amino-thiolysis of a sample containing both intermediates with the insertion of the amino group on the episulfide site followed by an intramolecular thiolysis with double functionalization of the matrix [2].

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Plasma-Catalysis: From Catalyst Screening to Gas Cleaning Process

I-13

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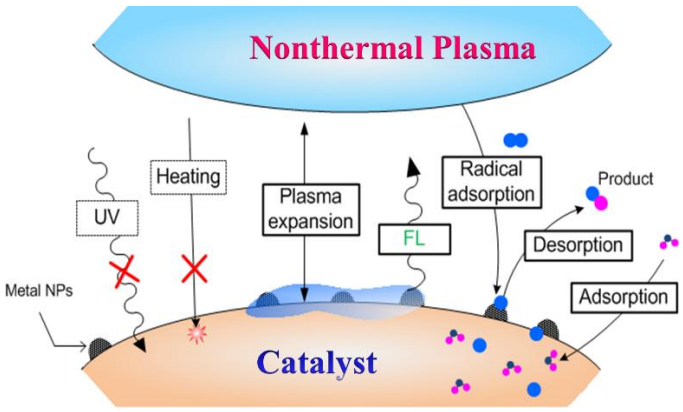
Nonthermal plasma (NTP) can induce unique chemical reactions at atmospheric pressure and normal temperature. The chemical potentials of NTP have been applied for the removal of various pollutants including volatile organic compound (VOC), odor, NOx, and particulate matter (PM). Understanding of the physical interaction between nonthermal plasma and catalyst is important for the further optimization of the system [1-3]. However, fundamental information on the interaction of NTP with catalyst is still lack and need further studies. One important physicochemical factor determining the chemical performance of plasma-catalysis is the propagation of surface streamers on the surface of catalyst [4]. Screening of catalyst should consider the type of reactor configuration (single-, two-, multi-stage, and cycled system). This presentation will cover from the current understanding the interaction of plasma and catalyst to the possible applications in various chemical reactions.



Interaction of plasma and catalyst.

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Plasma actuators and flow control

I-14

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Surface dielectric barrier discharge (DBD) based on two electrodes mounted on both sides of a dielectric have been widely studied for 15 years for their application in aerodynamic flow control by plasma actuators. On one hand, surface DBD supplied by an ac high voltage produces an electrohydrodynamic force that results in an electric wind based-wall jet. Single DBD can produce mean force and electric wind velocity up to about 1 mN/W and 6 m/s, respectively (Figure 1). With multi-DBD designs, velocity up to 11 m/s has been measured and force up to 350 mN/m. On the other hand, if the high voltage has a nanosecond repetitively pulsed waveform, the sudden gas heating at the dielectric wall results in a pressure wave with pressure gradient up to 10 kPa. When the plasma actuator is mounted at the wall of an aerodynamic profile, these both mechanical phenomena (EHD force and pressure wave) can interact with the boundary layer and modify the near-wall flow, resulting in the control of the whole flow.

The ability of these different plasma actuators to manipulate airflow has been widely studied all over the world. Although it is not possible to summarize all these studies, major results obtained at University of Poitiers will be discussed during the oral presentation. We will focus on turbulent separation control along an airfoil (Figure 2) and manipulation of a shear layer developing downstream of a backward-facing step. In both cases, we will highlight the key role of the frequency actuation and the actuation location on the control effectiveness.

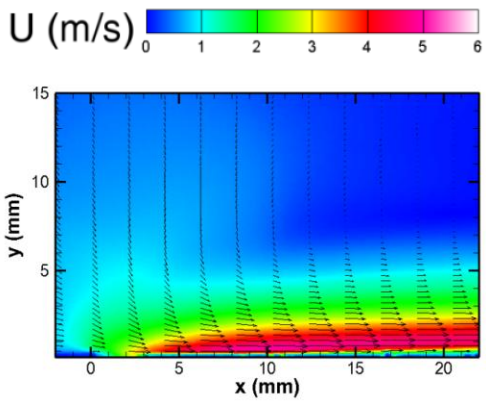

Figure 1. Velocity field produced by a single DBD.

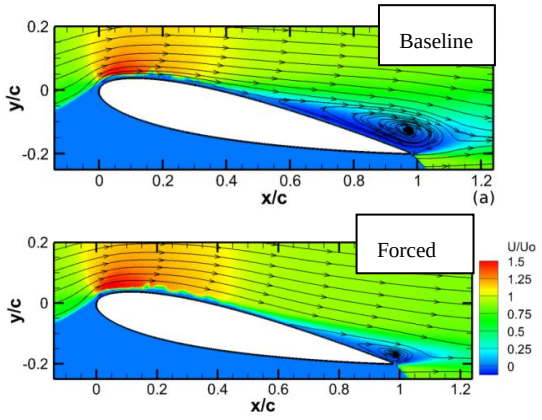

Figure 2. Flow control by DBD (Re = 1.33×10^6).

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The major contribution of low-temperature plasma to surface science and technology

I-15

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Low-temperature plasma has significantly contributed to quite different areas of science and technology such as materials processing and treatment, mainly due to two reasons: 1- plasma parameters can be set at many orders of magnitude. This possibility allows the plasma processes to be controlled both in thermodynamic equilibrium conditions and in non-equilibrium conditions; and 2-because it is an environmentally clean technology. The aim of this paper is to present different findings from low-temperature plasma research. All the studies were conducted at the Plasma Laboratory (LabPlasma) at State University of Santa Catarina-UDESC-Brazil. The following topics will be discussed: 1- deposition through Plasma Sputtering of titanium oxide films doped with niobium in two different stoichiometries, TiO_2:Nb and Ti_2O_3:Nb. It is noteworthy that these films have several technological applications, for example, in photocatalysis and Transparent Conductive Oxides film (TCO), which is used in photovoltaic cells; 2- creation of micro-roughness and nano-roughness on surface of parts (cathode) through high energy ion bombardment activated by plasma; in this case, the resulting surface can be used, for example, to improve the adhesion of dental implants to the bone; 3- plasma surface treatments such as nitriding and oxidation. These treatments have technological and environmental advantages in comparison to other thermochemical and electrochemical methods of metal surface treatment; 4- plasma sterilization on polymer surfaces, which can be used to sterilize medical-hospital material; 5- functionalization of polymer surfaces by plasma in order to change its surface energy; 6- finally, it will be showed a new power supply for plasma generation that allows better control of voltage pulses and increases the plasma ionization rate twice, when compared to DC plasma. It will be discussed the waveform for powering up the electrons and ions in the glow discharge plasma region.

Oral Communications

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Impact of packing material on plasma behavior in a catalyst packed DBD for CO_2 and biogas conversion

O-1

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Packed bed plasma reactors (PBRs) are a promising technology for industrial gas processing, particularly for CO_2 and CH_4 conversion to syngas. The challenge of discovering effective catalytic packing materials is exacerbated by contradictory and inconsistent results between different experiments. In order to progress PBR science, it is critical to improve the understanding of the behavior of plasma discharges within the packed bed.

Plasma-catalytic reactions are often commended for the synergistic effects caused by interactions between the catalyst and the plasma. The nature of these interactions are strongly influenced by the properties of the packing material [1, 2]. There are a wide range of packing parameters that influence the discharge behavior, therefore understanding the contribution of each variable to the overall reactor behavior is a complex problem. This work systematically addresses two important variables in detail, particle size and packing material dielectric constant.

Firstly, the effects of packing particle size (180 – 2000 μm) of two commonly used PBR packing materials ($BaTiO_3$ and Al_2O_3) on CO_2 splitting over a range of reaction conditions is presented. Significantly, the trends in CO_2 conversion observed are explained through electrical diagnostics of the reactor behavior. These diagnostics show that CO_2 conversion is strongly correlated with discharge type and the extent of partial reactor discharging.

Secondly, the effects of dielectric constant on discharge phenomena is demonstrated through the use of a novel single particle “packed bed” reactor. This data relates the applied electrical properties and reaction conditions with breakdown voltage, reactor burning voltage, discharge expansion and charge transfer mechanisms in CO_2, CH_4 and argon.

Although these variables have, to some extent, been studied before, the data and methods presented in this work offer a previously unseen insight into their respective contributions to packed bed discharge phenomena.

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Investigation on SiOx film deposition using dielectric barrier discharge plasma

O-2

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Dielectric barrier discharge plasma enhanced chemical vapor deposition system (DBD-PECVD) with substrate temperature controlling between room temperature and 300 ^{o}C was established and SiO_x film was deposited using tetraethyl orthosilicate (TEOS) and oxygen gas mixtures (or with N_2 and Ar addition) as the precursors. The influence of the parameters (precursors' composition, the discharge voltage, the discharge frequency, the reactor pressure and the substrate temperature) on the properties of the film were systemically studied. The thickness and refractive index of the deposited films were characterized by using the optical profilometer (FILMETRICS F50). Chemical bond structure of the deposited SiOx film was analyzed by using Fourier Transform Infrared Spectroscopy (IRPrestige-21). The crossection of the deposited SiO_x film was characterized by using scanning electron microscopy (SEM). Experimental results show that the film deposition rate and composition was strongly affected by the precursor ratio and the discharge pressure as well as the substrate temperature.

Keywords: SiO_2 film; DBD-PECVD; precursor ratio; Thickness; Refractive index;

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Ozone generation by nanoseconds pulsed discharge in compressed air

O-3

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Non-thermal plasma discharges have recently drawn considerable attention as a promising technology for combustion enhancement in engines. In addition, the addition of ozone into the cylinder has been reported to be effective in improving combustion characteristics.

In such situation, nanoseconds (ns) pulsed discharge which is one of the non-thermal plasma has attracted attention as a higher energy efficiency technique of ozone production. Ozone generation system has developed an using ns pulsed discharge plasma with a 5 ns pulsed duration. Our previous research has been reported that a short pulsed width is desirable for efficient production of radicals and excited species [1].

However, research thus far has been limited to atmospheric pressure. In order to aim the application to the internal combustion engine of previously mentioned, the study of effect of pulse width discharge in high compressed air. In this study, it is investigated effect of pulsed width on the production of ozone in compressed air using pulsed positive corona discharge(5,20,800 ns).

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CO_2 conversion in a gliding arc plasmatron

O-4

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In recent years, there has been increased interest in CO_2 splitting by plasma to produce CO and O_2 [1]. Thermodynamically, this reaction requires a lot of energy (i.e., 2.9 eV/molec or 279.8 kJ/mol), which would typically be supplied in classical processes by heating the gas. In a non-thermal plasma, however, the gas can remain at a relatively low temperature, due to the energetic electrons that are created which can activate the gas by electron impact excitation, ionization, and dissociation. Several types of plasmas have been applied for CO_2 conversion, but most research is carried out with one of the following: dielectric barrier discharges (DBDs) [2], microwave plasmas [3], and gliding arc discharges [4]. The latter are very promising in terms of energy efficiency.

A classical gliding arc reactor typically consists of two plane diverging electrodes between which the gas flows. Nevertheless, this configuration has a few disadvantages since it is incompatible with different industrial systems, the gas treatment is non-uniform and the residence time is short. Therefore, a three-dimensional gliding arc reactor was designed at Drexel Plasma Institute (Philadelphia) in which the gas enters through a tangential inlet so that a vortex flow is obtained. Such a gliding arc plasmatron is used in this work to study CO_2 conversion.

The main goal of this research is to obtain a better understanding of CO_2 conversion in this type of plasma reactor and how this process can operate in an energy-efficient way for industrial implementation of this technique. More particularly, the effect of the applied power and flow rate on CO_2 conversion and energy efficiency are studied. Furthermore, the influence of the electrode geometry is investigated in order to determine the effect of the vortex flow on CO_2 splitting.

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ISNTP-10
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Oxidation and removal of NO in mist by non-thermal plasma: Effects of discharge electrode configuration and polarity

O-5

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A coaxial non-thermal plasma (NTP) reactor was used for oxidizing and removing of NO in mist. In the NTP reactor, it is possible that NO is oxidized to NO_2 by active species generated by high voltage discharge, and mist from the wet desulfurization system serves as an absorption solution for NO_x. In this study, the effects of discharge electrode configuration and polarity on O_3 formation, NO oxidation and NO_x removal by NTP in simulated flue gas were investigated. The results show that decrease the discharge gap and increase the tooth slice number, as well as thorn number significantly influences the energy density in the plasma reactor and improves the efficiencies of NO oxidation and NO_x removal for a fixed applied voltage. The discharge length has little effect on NO oxidation and NO_x removal. The positive dc discharge exhibits much higher O_3 formation, NO oxidation and NO_x removal performances than the negative one. For the positive dc discharge, when 80% NO oxidation is acquired, the energy yield is 3.1 gNO/kWh. The discharge electrode structure has been optimized and this process demonstrates that NO oxidation by NTP and subsequently absorption by mist are feasible and have a great value of practical application.

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Unwanted NOx production during the conversion of CO2 in a dielectric barrier discharge in the presence of N2 and how to prevent it O-6

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Carbon dioxide conversion and utilization has gained significant interest over the years, due to the steadily rising concentration of CO2 in earth's atmosphere. A novel gas conversion technique with great potential in this area is plasma technology. To-date a lot of research has already been performed in this area, but mostly on pure gases [1]. In reality, most industrial and CCSU/R gas flows contain impurities, which is mainly N2 in most cases. Therefore, we performed an extensive combined experimental and computational study on the effect of N2 in the range of 1–98% on CO2 splitting in a dielectric barrier discharge (DBD) plasma [2]. The presence of up to 50% N2 in the mixture barely influences the effective (or overall) CO2 conversion and energy efficiency, because the N2 metastable molecules enhance the absolute CO2 conversion, and this compensates for the lower CO2 fraction in the mixture. Higher N2 fractions, however, cause a drop in the CO2 conversion and energy efficiency. Moreover, in the entire CO2/N2 mixing ratio, several harmful compounds, i.e., N2O and NOx compounds, are produced in the range of several 100 ppm [2]. The reaction pathways for the formation of these compounds are explained by performing a chemical kinetics analysis, based on which we propose some solutions to prevent the formation of N2O and NOx compounds. We believe that the only option is to inhibit the reaction between the N-species and the O-species. In a previous study we had already proven the effectiveness of adding a Hydrogen source [3], so therefore we also explored here the effect of adding a hydrogen source on a chemical level as an in-situ oxygen scavenger to prevent the formation of NOx and N2O.

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Persistent Organic Pollutants Treatment in Wastewater using Nano-Seconds Pulsed Non-Thermal plasma

O-7

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Persistent organic pollutants (POPs) are bioaccumulative and environmentally persistent substances. POPs cannot be decomposed by conventional water treatments. For this reason, a new treatment method is required. Several attempts to decompose organic compounds have been performed using various types of plasma reactors [1]. Nano-seconds (ns) pulsed discharges enable higher energy efficiencies of plasma processing. Its advantages have been already performed at gas phase treatment such as NOx treatment and ozone generation [2-3]. On the other hand, there are few reports on the water treatment using ns pulsed discharge plasmas. In this study, we tried to decompose real industrial wastewater in POPs using ns discharge method by spraying wastewater into gas phase plasma region. We were evaluated for the influence of the pH, gas flow late and liquid flow rate of the decomposition of wastewater using ns discharge method. The time course of pH and concentration of Total Organic Carbon (TOC) in the solution evaluated at several treatments.

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Acid/Base Catalysis of Phenol Degradation by Non-Thermal Plasma Discharge

O-8; P-20

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Hormones, drugs and pesticides are among the most feared contaminants by the scientific community because its accumulation in living organisms, leading to a chain of environmental problems.[1] The use of non-thermal plasma (NTP) discharges for the abatement of aqueous matrices of those organic pollutants has been widely studied. In this scenario, oxygen plasma can induce the formation of primary (e.g, radicals) and secondary species (e.g. H_2O_2, O_3) as well as other reactive oxygen species responsible for degradation of organic matter through successive oxidation reactions.[2] It is known that phenol OH-adduct and hydroxyl radicals spontaneously undergo acidic or basic catalysis, lacking water to give the phenoxyl radical which is stabilized by resonance.[3] However, the current work of the NTP research field ignores the contribution of specific and general acid/base catalysis on the degradation of organic compounds, leaving a gap of information to be studied. The main aim of this work is to show the contribution of acid/base catalysis in phenol degradation, chosen as a model molecule. The tests were conducted in an oxygen atmosphere where the NTP discharge was generated above a set of phenol solutions prepared in different aqueous buffers (inside the pH range of 3 to 12) and of different buffering capacities in order to established the role of general and specific acid/base catalysis on the degradation of phenol by O_2-NTP.

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Nanocrystalline TiO_2 –WO_3 bilayered films produced by reactive sputtering for photocatalytic applications

O-9

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In recent years, the pollution of the wastewaters with dyes is becoming a major environmental problem due to the growing use of a variety of dyes. Dyes usually have a synthetic origin and complex aromatic molecular structures, which are very stable and difficult to biodegrade. So, there has been an increasing interest in developing new methods, more effective than the conventional processes, to eliminate these pollutants. Advanced oxidation processes, characterized by the generation of hydroxyl radicals and superoxide anion, when a semiconductor catalyst absorbs radiation when it is in contact with water are a promising technology. Although TiO2 is an important semiconductor photocatalytic material, the large band gap (~3.2 eV) limits its optical absorption only in the UV range, which hampers its application in the visible spectral region. A lot of researches have be done to improve the TiO_2 activity and showed that the efficiency can be enhanced in heterogeneous semiconductors systems because the recombination of photogenerated charge carriers are suppressed [1]. Photocatalysts can either be used as powders or as supported films. The latter configuration is advantageous since solves important problems (eliminate the separation/filtration steps, the problematic use in continuous flow systems and particles aggregation). Among the several techniques that can be used to prepare catalytic material in film form the sputtering method presents several advantages [2]. This work reports the preparation and characterization of TiO_2/WO_3 bilayered films produced by DC-magnetron sputtering for photocatalytic applications. The crystallographic, optical and morphological properties of WO_3 and the TiO_2 layers were studied. The films photocatalytic activity was tested, under visible irradiation, on the decolorization of Rhodamine 6G aqueous solutions.

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Combined electric wind and non-thermal plasma for gas cleaning

O-10

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Non-thermal plasmas are used in air purification systems to complement and improve the effect of the installed filters and increase their life time. This contribution discusses the effect of a combination of plasma and ionic wind on the decomposition of volatile organic compounds. Therefore, synthetic air containing up to 60% r.h. water and up to 100 ppm methyl ethyl keton (MEK) as a typical VOC found in the exhaust air of cooking processes is treated with a plasma source enabling the additional generation of an ionic wind. Therefore, it consists of a dielectric barrier discharge (DBD) electrode and a remote ion extraction electrode. The DBD is energized with a low frequency AC high voltage whereas the ion extraction electrode is connected to high voltage DC. The effect of the ionic wind on chemical processes is analyzed by FTIR-spectroscopy, FID-measurements. Optical investigation enables the study of the effects on aerosols and flow dynamics. It is found that the ionic wind has a strong effect on smoke guided through the plasma source. Additionally, an improved decomposition of MEK is detected (see Fig. 1) accompanied by an increased production of carbon dioxide and monoxide indicating that MEK is mainly mineralized.

Additionally, the dependency of the effects of the ionic wind on the relative humidity and the gas flow is studied, as well as the electrode cleaning effect.

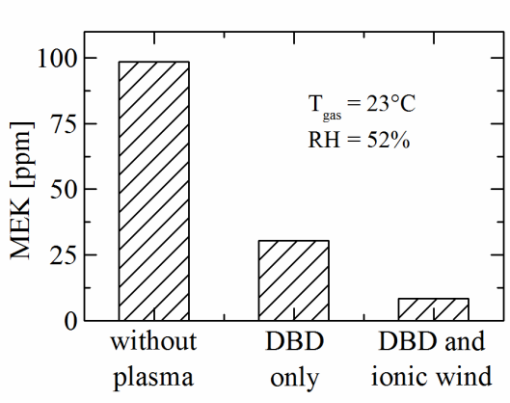

Fig. 1: Decomposition of methyl ethyl keton (MEK) with DBD only and additional ionic wind

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Electro-hydrodynamically Enhanced Non-thermal Plasmas: Filtration and Inactivation of Airborne Infectious Aerosols

O-11

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Of the various modes of disease transmission, airborne transmission remains poorly understood for both humans and animals. This represents a substantial challenge to agriculture where conventional bio-security measures have focused on preventing surface transmission of viruses and bacteria on worker clothing or equipment to protect confined livestock. However, avian influenza and porcine reproductive and respiratory syndrome (PRRS) are among a growing list of animal diseases determined to have significant transmission probability via the air: viable copies of the virus that causes PRRS has been detected in the air up to 4 kilometers downwind of infected barns [1, 2]. Non-thermal plasmas have undergone substantial testing and demonstration for the destruction of chemical contaminants in air, however treatment of biological contaminants in air is much less well developed. One contributor to this distinction almost certainly is the challenge of modeling both the electrical and the biological interactions between the infectious aerosols and the plasma. This study leverages advances made in the numerical simulation of industrial electrostatic precipitators [3, 4] to demonstrate how electro-hydrodynamic (EHD) effects can be used to enhance inactivation of airborne viruses by non-thermal plasmas (NTPs). COMSOL™ Multiphysics software suite is used to numerically simulate EHD-induced secondary fluid flows and their impact on the dynamic behavior of charged aerosols and their exposure to reactive radicals. The results suggest EHD effects result in aerosols receiving twice the reactive radical dose (integral of radical concentration over a particle path) that would be received without EHD effects. Further optimization of this concept, for which a provisional U.S. patent has been granted, is ongoing.

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CO_2 Hydrogenation in a non-thermal plasma aided by supported metal catalysts
O-12; P-2

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The globally significant utilization of fossil fuels led to increased annual emission of CO_2 in recent years[1]. Among all the possible conversion routes of utilizing CO_2, the hydrogenation of CO_2 to CH_4 is a promising way. The major steps involved in the hydrogenation of CO_2 to CH_4 are thermodynamically favorable. However, the reaction rate is generally low due to the kinetic limitation. As a consequence, the catalytic hydrogenation of CO_2 to CH_4 occurs at elevated temperatures in the conventional reaction system. The high reaction temperatures result in the sintering of the metal active phases (such as Ni) and coke deposition, which lead to catalyst deactivation. Therefore, it is desirable to conduct CO_2 hydrogenation at low temperatures. Because non-thermal plasma is highly energetic and it is also in a non-equilibrium state, it has been frequently used in the activation of stable molecules including CO_2. In a gas discharge, both CO_2 and H_2 are easily dissociated at low temperatures in a non-thermal plasma [2].

In the present paper, CO_2 hydrogenation was conducted with H_2 in a plasma-catalyst hybrid system, in which a non-thermal plasma generated by dielectric barrier discharge was coupled with supported metal catalysts. Various SiO_2-supproted transition metals, including Co, Ni, Cu, Mo, and W, were tested as the catalysts for CO_2 hydrogenation in the plasma. Among the transition metals mentioned above, Co/SiO_2 exhibited the highest activity, and the major product was CH_4. SiO_2, Al_2O_3, TiO_2, MgO and mesoporous MCM-41 were used to support Co species, and the effect of catalyst support on the catalytic performance was investigated. The activities of Co/SiO_2, Co/MCM-41, and Co/MgO were comparable and they were much higher than that of Co/Al_2O_3, whereas Co/TiO_2 hardly exhibited catalytic activity. No deactivation was observed in the plasma-induced CO_2 hydrogenation aided with Co/SiO_2 in a 200-hr test run.

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Detection of reactive oxygen species transported into liquid bottom by atmospheric non-thermal plasma jet

O-13

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Supply of reactive oxygen species (ROS) to targets through liquid layer by plasma is known to be important for biomedical applications. We have studied ROS transportation into a liquid bottom by plasma jets [1, 2]. ROS transportation into liquid bottom was studied under various experimental conditions using KI-starch gel reagents.

Fig. 1 shows a schematic of our experimental setup. The KI-starch gel reagent which induces color reactions with various ROS was used as a ROS detector. A water layer was supplied onto the gel reagent, and plasma jets were irradiated onto the water surface. ROS transported into the water bottom were detected by the gel reagent.

Fig. 2 shows typical plasma-transported ROS distribution patters at the water bottom for the flow rates of (a) 1 L/min and (b) 3 L/min. We also obtained the relative ROS concentration profiles by an absorbance measurement along the AB line of the color reactions. In the present study, we will present results on ROS detection at the liquid bottom under various experimental conditions, and discuss ROS transportation into the liquid bottom by plasma jets.This study was partly supported by a Grant-in-Aid for Science Research from the Japan Society for the Promotion of Science (Grant Number 25820113).

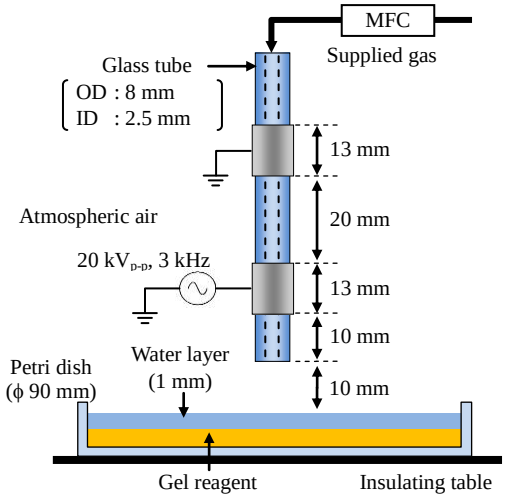

Fig. 1. Schematic diagram of experimental setup.

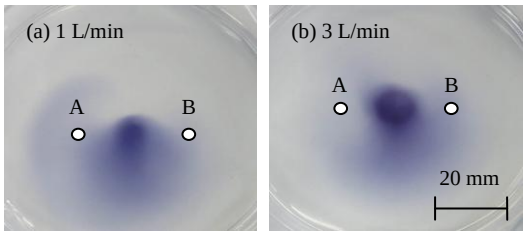

Fig. 2 Plasma-transported ROS distribution patterns at the water bottom.

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Spent Batteries Final Treatment using Thermal Plasma

O-14

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The growth in the use of wireless devices, notebooks and other electronic products has led to an ever increasing demand for batteries, leading to these products being commonly found in inappropriate locations. Due to political pressure and according to the environmental legislation which regulates the destination of spent batteries, in several countries the application of reverse logistics to hazardous waste is required. Thus, some processes have been developed with the aim of providing an appropriate destination for these products.

In this context, a method for the treatment of spent batteries using thermal plasma technology is proposed herein. The pyrolysis of the samples was carried out in a plasma furnace with a transferred arc torch. The furnace is comprised of a plasma torch acting as a cathode and a graphite sheet acting as the anode and sample support. The efficiency of the method was tested through the determination of parameters, such as total organic carbon, moisture content and density, as well as analysis by atomic absorption spectrometry, scanning electron microscopy and X-ray fluorescence using samples before and after inertization.

The value obtained for the density was 19.15%. The TOC results indicated 8.05% of C in the batteries prior to pyrolysis and according to the XRF analysis Fe, S, Mn and Zn were the most stable elements in the samples (highest peaks). The efficiency of the paste inertization was 97% for zinc and 99.74% for manganese. The results also showed that the inertization of the metals was efficient and the addition of sand to the moist paste of the batteries before pyrolysis reduced the volatilization of the metals analyzed and aided the inertization.

Therefore, the use of the thermal plasma for pyrolysis besides providing the inertization of metals also reduced the volatilization of these metals, indicating that this is a clean and environmentally safe approach to the final treatment of residues, generating inert subproducts which could be reused in the production of pavements and industrial tiles and in metallurgical processes.

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Selective Hydrogen Production by Non Thermal Plasma Processing of Residual Heavy Oil

O-15, P-26

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The predominant chemical reactions conducted in a cold plasma reactor are essentially dehydrogenations when hydrocarbons are the reactive. Taking advantage of this characteristic, the present study is focused on the production of hydrogen from residual heavy oil, using argon as carrier gas. The main goal is to consider the process as an alternative method for production of a gas rich in hydrogen and free of carbon monoxide.

The present paper analyzes the production of hydrogen when a residual heavy oil is processed in nonthermal plasma chemical reactors. The products distribution exhibited high concentration of hydrogen as a consequence of light olefins production. The high concentrations of olefin compounds of low molecular weight can be drawn taking into account that dehydrogenation is a common reaction occurring in plasmas.

The main goal is to consider the process as an alternative method for production of a gas rich in hydrogen and free of carbon monoxide. Furthermore, light olefin hydrocarbons such as ethylene and propylene are commonly employed as additives in the NOx removal conversion systems for power plants and vehicles exhaust gases. The present research was initiated in the Department of Ecological Engineering, Toyohashi University of Technology, Japan, in 1998 with the purpose to investigate a nonthermal plasma plate-to-plate reactor to convert a residual heavy oil (high molecular weight hydrocarbons, essentially paraffins in the range of n-C10 to n-C25, into light hydrocarbons (mainly olefins) to be employed, for example, as gasoline components for the new generation of engines in the so-called “hybrid process”; or to be added in small amounts to certain catalytic processes for reduction of nitrous oxides compounds in the power plants and vehicles exhaust gas treatments.

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Direct conversion of methane with Non-thermal and Thermal Plasma

O-16

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Direct decomposition of methane has been investigated with thermal and non-thermal plasma. For investigating the thermal plasma process, a rotating arc plasma reactor has been used, which generates a high temperature reaction zone. Methane and carrier gases, such as Ar and N_2, pass through this high temperature reaction zone, and then are quickly cooled down by releasing the heat to the surroundings. Typically, the residence times of the reaction zone are less than few msec. The test results show that the performance of the reactor is significantly dependant on the temperature and the residence time. For investigating the non-thermal plasma process, a DBD (Dielectric Barrier Discharge) reactor packed with ceramic beads has been used. An intensive parametric study has been conducted by changing the physical scales and geometries of the beads [1], packing materials (Pt-Al_2O_3, MgO-Al_2O_3, TiO_2, Al_2O_3, etc.), carrier gases (He, Ar, Xe, Kr) [2], and the operating temperature. The test results suggest that high temperature electrons plays a critical role in methane activation. For example, a higher electrical field obtained by changing the packing beads and carrier gases leads to a better performance in methane activation. The test results, unfortunately, show that typical catalysts coated by metals like Pt and Ni might not be appropriate as packing materials. At high temperature conditions, in which one can expect synergy effects of plasma and catalyst, these metal catalysts tend to result in arching problem.

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Mineralisation of ethylene by plasma catalysis

O-17

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Air pollution has a huge detrimental impact worldwide: in 2012 around 7 million people died as a result of bad air quality [1]. Due to an increased gas tightness of buildings in recent years, more advanced technologies for indoor air purification are needed.

In order to enhance the already existing non-thermal plasma reactors, plasma catalysis as combined technology between catalysis and plasma is proposed to overcome the deficiencies of NTP. Plasma catalysis combines the advantages of high product selectivities from catalysis and the fast start-up from plasma technology.

In this study, a photocatalytic TiO_2 coating is applied on the collector electrode of a corona discharge unit, whilst the electric conductivity of the collector electrode is assured [2]. The conversion efficiencies of ethylene, the CO_2 formation and the formation of ozone in the reactor was determined before and after applying the coating when using a predetermined window of operation: 21% O_2, negative corona of 15 kV.

In this plasma catalytic system, an enhanced mineralization of ethylene is observed while the production of the harmful by-product ozone drastically decreases. This shows potential of plasma catalysis as indoor air purification technology.

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Degradation of phenol by different pulsed discharge modes in combination with TiO_2 photocatalysis

O-18

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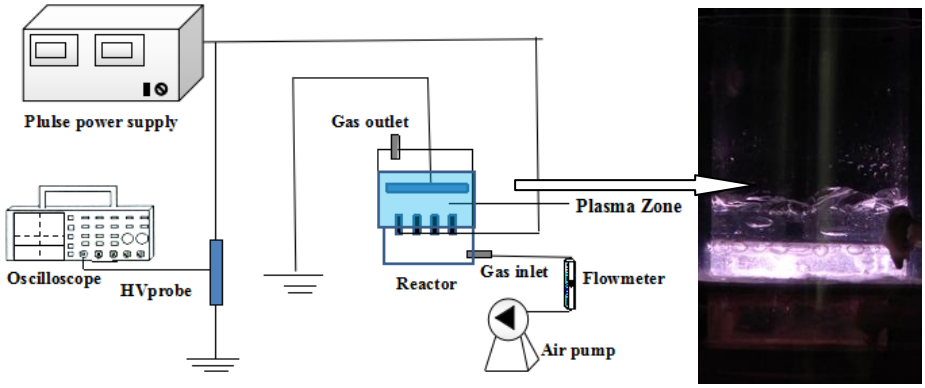
TiO_2 photocatalyst (P-25) was tentatively introduced into pulsed high-voltage discharge process for non-thermal plasma-induced photocatalytic degradation of organic pollutant. In present study, degradation of phenol by the pulsed discharge plasma-TiO_2 catalytic between needle-to-plane electrodes has been investigated in three discharge modes: spark, spark-streamer mixed and streamer mode, the schematic diagram of the experimental setup is shown in Figure 1. The experimental results showed that the phenol removal rate for different discharge modes are spark> spark-streamer> streamer in plasma discharge system. In plasma/TiO_2 system, the phenol removal has been found to be most effective if the discharge operates in the spark-streamer mixed mode, which are characterized by high intensity ultraviolet radiation. The main intermediate products produced by discharge during the treatment process were hydroquinone, catechol, and 1,4-benzoquinone. At the same time, higher formation of 1,4-benzoquinone as the main primary aromatic by-product while benzoquinone and catechol were only found in negligible amounts. In additions, our results suggest that undesired byproducts 1,4-benzoquinone decreased in the presence of TiO_2, thus improving the oxidation efficiency of phenol, as shown in Fig.2. A greater degree of oxidation of intermediates and higher energy efficiency in phenol oxidation were observed with the plasma-TiO_2 systems.

Continue next page



(a) (b)

Fig. 1. Schematic diagram of (a) the experimental setup and (b) the reactor.

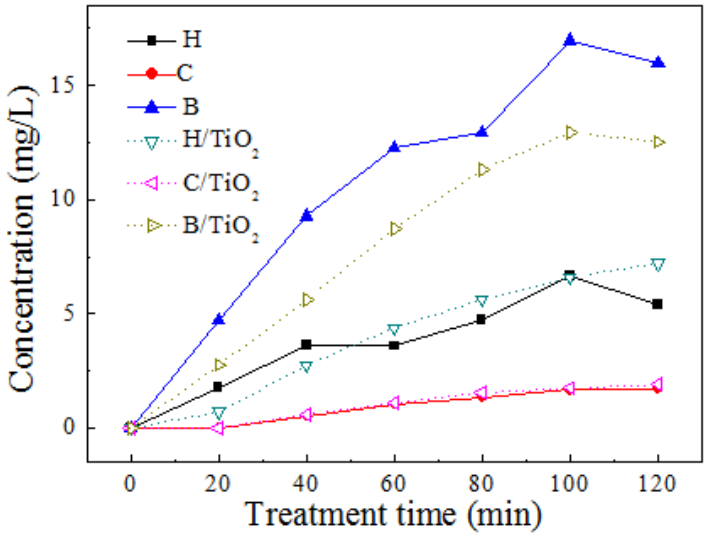


Fig. 2. Phenol degradation and by-products formation in discharge system with TiO_2

(H: Hydroquinone, C: Catechol, B:Bezoquinone)

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Multi-Step Modeling of a Rotating Gliding Arc (RGA) Reactor

O-19

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Thermal plasma is generated at high pressure (>1 bar) and is characterized by low degree of gas ionization, poor selectivity for some chemical reactions and poor energy efficiency. On the other hand, non-thermal plasma is generated under vacuum conditions and high selectivity and energy efficiency can be reached. However, typically a combination of thermal and non-thermal plasma is desired for industrial applications, which can be achieved through transient gliding arc discharge mechanisms. In this context, rotating gliding arc (RGA) reactors [1] can be highlighted as an efficient design which can comply with the expected project requirements. Nevertheless, several complex and coupled physics take place in this equipment and suitable modeling strategies are needed for its optimization. In this work we applied a multi-step computational modeling approach to investigate the fluid dynamics and the electrostatics within a RGA reactor based on a bench scale prototype. Moreover, the chemical composition at the electrode region was evaluated [2]. Finally, the breakdown voltage and the corona inception voltage were investigated through a home-made code based on Pashen's [3] and Peek's [4] laws.

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Plasma gas cleaning process for the removal of model tar from biomass gasification

O-20

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The gasification of biomass represents a major thermochemical route to produce a high energy value syngas from a source which is renewable and CO_2-neutral [1]. However, one of the major issues in the gasification process is contamination of the product syngas with tar (a mixture of compounds containing polycyclic aromatic hydrocarbon and oxygenates). The formation of tar causes major process and syngas end-use problems, including tar blockages, plugging and corrosion in downstream fuel lines, engine nozzles and turbines.

Non-thermal plasma technology provides an attractive alternative to the conventional catalytic route for the removal of tar. In non-thermal plasmas, the overall gas temperature remains low, while the electrons are highly energetic, which is sufficient to break down most chemical bonds of molecules and produce highly reactive species: free radicals, excited atoms, ions and molecules for chemical reactions [2-4].

In this work, a laboratory-scale gliding arc plasma reactor has been developed for the removal of model tar (toluene) at low temperatures. The effect of a wide range of processing parameters (e.g. water vapor amount, discharge power, initial toluene concentration) on the plasma processing of toluene has been investigated in terms of carbon conversion, selectivity of gas products and energy efficiency of the plasma process.

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Posters

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Kinetic Study of Paraquat Degradation in Aqueous Media by a Corona Air Plasma System
P-1

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In this work, a corona plasma reactor system was built, in order to study the degradation of paraquat (PQ) in aqueous media. Effects of temperature and initial PQ concentration ($[PQ]_0$) during degradations on the observed rate constant (k_{obs}) were examined by the univariate method. The effect of temperature was evaluated from 5 to 45 ^oC range, using $[PQ]_0$ = 10 µM and the effect of $[PQ]_0$ was investigated using 10, 15, 30 and 50 µM, while keeping the temperature at 25 ^oC. The plasma was generated using atmospheric air contained in the plasma reactor, aiming to minimize costs, focusing an environmental application. Kinetics of the PQ degradation were followed by scanning UV-Vis spectrophotometry (from 200 to 800 nm) and the produced species (nitrite and nitrate) were characterized by comparison with their reference and experimental spectra. PQ concentration over degradation time was determined spectrophotometrically based on its reaction with dehydroascorbic acid in a basic medium, producing a blue PQ radical (λ_{max} = 600 nm). PQ degradation kinetic followed a pseudo second order behavior, increasing k_{obs} by increasing temperature ($k_{obs} = 1.5x10^{-1}$ M^{-1} min^{-1} and $3.1x10^{-1}$ M^{-1} min^{-1} at 5 ^oC and 45 ^oC, respectively). The Arrhenius plot ($\ln k_{obs}$ versus 1/T) was linear within temperature range, and the degradation activation energy (E_a) was 13.88 kJ mol^{-1}. Increasing $[PQ]_0$ from 10 µM to 50 µM decreased k_{obs} from $2.0x10^{-1}$ M^{-1} min^{-1} to $2.2x10^{-2}$ M^{-1} min^{-1}, at 25 ^oC. Nitrate (NO_3^-) and nitrite (NO_2^-) ions produced in the solution due to the air discharge (containing both N_2 and O_2), both followed a zero order kinetic rate ($k_{obs} = 2.6x10^{-3}$ M min^{-1} and $1.7x10^{-3}$ M min^{-1}, at 25 ^oC, respectively), indicating a direct effect of the plasma. These are results of the aqueous-phase post discharge reactions of dissolution NO_x in water, producing H_3O^+ (hydronium) ions, lowering the pH of the treated solution.

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CO_2 Hydrogenation in a non-thermal plasma aided by supported metal catalysts

P-2

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The globally significant utilization of fossil fuels led to increased annual emission of CO_2 in recent years[1]. Among all the possible conversion routes of utilizing CO_2, the hydrogenation of CO_2 to CH_4 is a promising way. The major steps involved in the hydrogenation of CO_2 to CH_4 are thermodynamically favorable. However, the reaction rate is generally low due to the kinetic limitation. As a consequence, the catalytic hydrogenation of CO_2 to CH_4 occurs at elevated temperatures in the conventional reaction system. The high reaction temperatures result in the sintering of the metal active phases (such as Ni) and coke deposition, which lead to catalyst deactivation. Therefore, it is desirable to conduct CO_2 hydrogenation at low temperatures. Because non-thermal plasma is highly energetic and it is also in a non-equilibrium state, it has been frequently used in the activation of stable molecules including CO_2. In a gas discharge, both CO_2 and H_2 are easily dissociated at low temperatures in a non-thermal plasma [2].

In the present paper, CO_2 hydrogenation was conducted with H_2 in a plasma-catalyst hybrid system, in which a non-thermal plasma generated by dielectric barrier discharge was coupled with supported metal catalysts. Various SiO_2-supproted transition metals, including Co, Ni, Cu, Mo, and W, were tested as the catalysts for CO_2 hydrogenation in the plasma. Among the transition metals mentioned above, Co/SiO_2 exhibited the highest activity, and the major product was CH_4. SiO_2, Al_2O_3, TiO_2, MgO and mesoporous MCM-41 were used to support Co species, and the effect of catalyst support on the catalytic performance was investigated. The activities of Co/SiO_2, Co/MCM-41, and Co/MgO were comparable and they were much higher than that of Co/Al_2O_3, whereas Co/TiO_2 hardly exhibited catalytic activity. No deactivation was observed in the plasma-induced CO_2 hydrogenation aided with Co/SiO_2 in a 200-hr test run.

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Discharge products measurement in a DC corona discharge over water by infrared spectroscopy
P-3

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Recently, the use of a discharged plasma for water treatment has been attracting attention [1] because the plasma can create OH radicals, an active species with a short lifetime, in the water or on its surface. OH is a strong oxidizer with an extremely short lifetime; therefore, its applicability for water treatment is challenging. However, since OH is generated close to the water surface in this treatment method, it is possible to use it for water treatment.

We have previously studied the decomposition of acetic acid, a model persistent organic compound, by a pulsed discharge on water using thin blade electrodes [2]. In this method, a discharge is generated between the blade electrodes and water surface. Therefore, this method directly treats water using a plasma discharge.

In the present study, we investigate the characteristics of acetic acid decomposition by a negative DC corona discharge over water. In addition, discharge products in a corona discharge over water are investigated by infrared spectroscopy. The corona discharge is 4 mm away from the water surface. Hence, this method is a nondirect plasma treatment. A DC corona discharge was chosen for application to the nondirect water treatment because of the simpler setup compared with a pulsed discharge. This study explores the mechanisms involved in the chemical reactions of active species for water treatment.

During processing, oxygen was supplied to the reactor. The optimal discharge treatment conditions were investigated by varying the gas flow rate. It was found that gaseous ozone and gas phase water are produced in the corona discharge by infrared spectroscopy, and these products concentration tends to increase with the decrease of the gas flow rate. Furthermore, as the gas flow rate decreased, the decomposition rate increased. Our results indicate that the concentration of discharge products over water are important for water treatment using a DC corona discharge.

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Magneto Hydro Dynamic Model of DC Thermal Plasma Torch
P-4

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Thermal plasma technology has been widely applied in modern industry like plasma spraying, thermal waste treatment, fuel reforming, plasma assisted combustion and many others. The temperature and velocity fields in the exit from the plasma torch are of special interest from a better understanding of the multidisciplinary physical process. In this paper, a magneto hydro dynamic model is developed to study the plasma behavior inside the DC thermal plasma torch and effect of post chamber on knowledge of the voltage-current and temperature-velocity characteristics. It is a three dimensional, steady state, k-ε turbulence model and assumes local thermodynamic equilibrium. The transport properties were calculated to approximate the effect of temperature variation. The influence of current and argon flow rate on the thermal plasma characteristics is presented. Predicted post chamber temperatures and thermal plasma torch voltages are comparable with measurements for different operating parameters.

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Evidence of the presence and reactivity of long life species in gliding arc plasma: Spatial and Temporal Post-Discharge reactions

P-5

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Two types of reactions were used to prove the presence and reactivity of long life species in gliding arc discharge studied in this paper; the temporal post-discharge reaction (TPDR) and spatial post-discharge reaction (SPDR). These reactions are mainly governed by the gas species produced in the discharge and their derivatives in aqueous solution. The TPDR concerns only species present in solution while the SPDR, in addition to those in solution, also takes into account the gaseous species produced in situ. In SPDR, the presence and the reactivity of these species were identified first by oxidation of iodide solution and the titration of H_2O_2 in the gas phase. The spectrophotometric study of a solution of Eriochrome black T (λ = 525nm) exposed in spatial post-discharge revealed that at t_{spd} = 1.5 min, it forms an intermediate compound which absorbs at λ = 752nm. After 30 min of exposure to the discharge, we obtain 71.13% of decolouration, with an overall kinetic order equal to one and a rate constant k = 0.0135 min^{-1}. In temporal post-discharge, under the effect of acids and oxidizing species (H_2O_2,ONOOH and their derivatives) present in plasma activated water, the conductivity of phenolphtalein solution increases suggesting that the compound is mineralized. The pH continued to decrease after one day and during the same period of time, the decolouration efficiency ranged between 18.33% up to 57.12%.

Keywords: Gliding arc plasma, Long life species, Plasma activated water (PAW), Post-discharge, Eriochrome black T, Phenolphtalein.

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Effect of the reactive gas mixture on electrical properties of TiO_2 thin films deposited by grid-assisted magnetron sputtering
P-6

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Titanium dioxide is a wide band gap semiconductor commonly used in solar cells [1] and microelectronic devices [2]. In such technologies, the electrical conductivity of this material plays a fundamental role in the working device [3]. In this paper, we conducted studies about titanium dioxide deposited by magnetron sputtering at different reactive gas mixtures in order to investigate the effect of the chemical composition of the films on their electrical properties. Films were analyzed by four-point probe and optical spectrophotometry. Results indicate that decreasing the oxygen concentration in the gas discharge leads to increase of the film conductivity and decrease of the optical transparency.

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Non-Equilibrium Gliding Arc and Dielectric Barrier Discharge Treatment of Liquids for Pathogen Removal from Food and Food-Contacting Surface

P-7

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The need for sterilizing agents in medical, food processing, and industrial applications has increased significantly. As a result, there is a very high interest in environmentally friendly, non-toxic and degradable yet potent (bio-)decontamination/disinfection technologies.[1] From a medical point of view, oxidizing agents are particularly useful for the high-level disinfection of medical devices and disinfection of hard surface.[1] Hydrogen peroxide (H_2O_2) has been shown to be a microbicidal active agent and its ability to sterilize is widely used and well-studied. The reason why hydrogen peroxide is so interesting is that it is an environmentally friendly, non-toxic and degradable, yet potent biocide. It has a broad spectrum activity, which includes efficacy against bacterial endospores, and with imaginative formulation, its surface corrosiveness and smell has been greatly reduced. It is particularly interesting for application in liquid as well as vaporized form, for antisepsis and for the disinfection of surfaces, medical devices and for room fumigation (the so-called deep clean). As such, the production of H_2O_2 by plasma technology is gaining a lot of interest for biomedical and (bio-)decontamination applications.[2]

We investigated the disinfection capabilities of water treated by a gliding arc plasmatron. The influence of the gas mixture (e.g. air, O_2), the water type (e.g. spring, distilled, deionized) and the effect of additives on the water properties (e.g. pH) and the production of active species (e.g. H_2O_2, $ONOO^-$, O_3, HNO_X, NO_X) was studied and their results will be presented.

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Synthesis of tungsten oxide nanorods using non-thermal plasma at atmospheric pressure

P-8

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This study concerns the synthesis of WO_3 nanorods in water from hydrated sodium tungstate ($Na_2WO_4.2H_2O$) using non-thermal plasma (NTP) with humid air as feeding gas. The acid properties of this plasma were exploited to convert the precursor into tungsten oxide VI.The synthesized tungsten trioxide nanorods was characterised by X-ray diffraction (XRD), FTIR spectroscopy, nitrogen physisorption and scanning electron microscopy (SEM). The results obtained from XRD showed peaks indexed to monoclinic phase and the average crystallite size was about 43nm. SEM morphology revealed that the synthesized WO_3 is an agglomeration of microparticles with rod like morphology. The infrared spectrum of plasma synthetized material shows all the peaks characteristics of WO_3. The specific surface area found by BET method was 40.8 $m^2.g^{-1}$. The important specific area obtained improves the application of the synthetized WO_3 as catalyst or electrochemical sensor.

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TiO_2 film on glass substrates: The effect of coat thickness on photocatalytic activity.

P-9

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Titanium oxide films were deposited by sputtering, using triode magnetron sputtering technique. TiO_2 films deposited on glass substrate with different thickness were characterized by the following techniques: x-ray diffraction (XRD), water drop contact angle measurements (before and after UV substrate irradiation), optical transmittance and AFM surface images. After deposition the samples were thermally treated in atmosphere air at 500°C during one hour. Results indicate that the contact angle between water drop and TiO_2 films reduces after heat treatment. After UV irradiation of film surface it was observed that the contact angle had a great reduction that is a characteristic of TiO_2. Before the heat treatment the contact angle was 85° and it fall to 53° after treatment. However, after 25 min irradiation with UV light the contact angle diminished to less than 10 degree that is characteristic of a super hydrophilic material. The photocatalytic activity of the films have been analyzed through a semi-quantitative method based on an ink indicator via a photo-reductive mechanism [1,2].

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Formation and the impact of photoionization on the Trichel pulses in air

P-10

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2D-axisymmetric analysis of the formation of the Trichel pulses in a needle-plane negative discharge will be presented in this paper. The numerical model consists of three continuity equations describing the generation, dissipation and motion of three charged species (electrons, positive ions and negative ions), one Poisson's equation for calculating the electric field [1] and three Helmholtz equations for describing the photoionization process. The model used for photoionization is based on the approximation suggested by Luque et al. [2] and extended later by Bourden et al. [3]. Comparison of the characteristics of the Trichel pulses (DC component of the pulse train and the frequency of the pulses) for the models with and without photoionization shows a 5% increase in both the DC current and the frequency of the pulses. Relative importance of different sources of production of electrons (impact ionization and photoionization) shows that comparing the number of electrons produced from each source does not give a complete picture of the importance of the sources and their distance from the needle tip should be considered as well.

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Multi-step Mechanism of Graphite Ozonization

P-11

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The kinetics and mechanism of graphite ozonization was studied with a number of techniques as XPS, FTIR, CHN, DRX, TGA and MEV. Ozone was generated through a DBD non-thermal plasma reactor. The O_3 concentration at the reactor outlet was measured with respect to the oxygen flow and applied tension. The kinetics of ozone insertion in the graphite was followed in a flow reactor by UV spectrophotometry with parallel flow-cells at 254 nm at 100 ^oC. The ozonization reaction at 100 ^oC occurred with insertion of O_3 as primary ozonide, or 1,2,3-trioxolane, in the graphite matrix followed by its decomposition producing a peroxide and an epoxide that eliminates oxygen in a consecutive reaction. The reaction was first-order with respect to ozone and first-order with respect to carbon. The final oxygen content of the graphite after ozonization corresponded to the total CO_2 eliminated at higher temperature. The decarboxylation reaction was studied at 600 ^oC. The pyrolysis of total desoxygenation and decarboxylation of graphite was also studied in the range of 600-900 ^oC. Thermal shock at 1000 ^oC of the decarboxylated samples, under Ar atmosphere, resulted in the total elimination of oxygen. The results are consistent to an ozonization mechanism of graphite similar to the reduction of SO_2 over carbons.[1,2]

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ISNTP-10
International Symposium on Non-Thermal/Thermal Plasma Pollution Control Technology and Sustainable Energy.
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Simulation of metal transport in grid assisted magnetron sputtering system
P-12

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Thin film deposition by magnetron sputtering is a well known method to modify surface properties. In this technique, atoms are ejected from a cathode target due to bombardment by energetic positive ions. These ions are generated in a magnetically confined plasma in front of the target. The sputtered atoms are transported in gas phase until deposit on the internal surfaces of the chamber. Among the variations in the magnetron sputtering system, stands out the grid assisted magnetron sputtering [1], where a grounded grid is inserted between target and substrate. The grid is the discharge anode, increasing the plasma confinement and resulting in a more stable discharge [1,2].

Using the free software SiMTra (Simulation of Metal Transport) [3, 4], depositions of different metals were simulated in conventional and grid assisted magnetron sputtering for different argon pressures (0.0 - 10.0 Pa). SiMTra uses Monte Carlo (MC) code to describe the transport of the sputtered particles through the gas phase in the vacuum chamber. The nascent energy and angular distributions of sputtered atoms were simulated with SRIM and used as input in SiMTra.

Simulation results show that the grid decreases the amount of deposited particles on substrate, but no clear trend is observed as a function of grid-to-target distance. It should be noted, however, that for pressures between 1.0 and 8.0 Pa, average energy of metal atoms arriving at the substrate is higher in grid assisted magnetron, irrespective of target material. It is caused due a higher probability of deposition of low energy atoms on the grid, as can be confirmed by analyzing the energy distribution function of the deposited atoms on substrate. The introduction of masks in front of the substrate also increases the average energy.

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Synthesis of graphitic carbon by thermal plasma decomposition of methane

P-13

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Thermal plasma processing of carbon sources using a plasma jet with high heat capacity is one of the most promising methods for the synthesis of new materials and hydrogen used in fuel cell and energy production. In this study is reported a method for obtaining graphitic carbon and hydrogen from the methane pyrolysis. The cracking operation was performed in the absence of oxygen using a thermal plasma direct current (DC) system (plasma torch and degradation chamber). The carbon structures, (Fig. 1) obtained without catalysts, were characterized by x-ray diffraction and scanning electron microscopy (SEM). The results showed the formation of graphitic carbon, (Fig. 1 A, D) carbon nanotubes (Fig.1 (C) and carbon black Fig. 1 B) during the process. Chromatographic analysis by Varian GC450 was also carried out for characterization and quantification of gaseous byproducts.

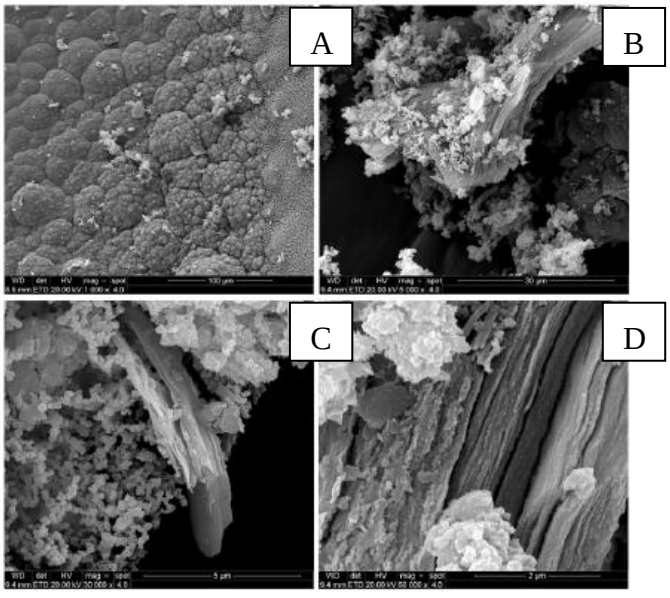

Figure 1 – Carbon structures.

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Influence of pH and buffer composition on the degradation of methyl orange azo dye by spark discharge non-thermal plasma: byproducts analysis

P-14

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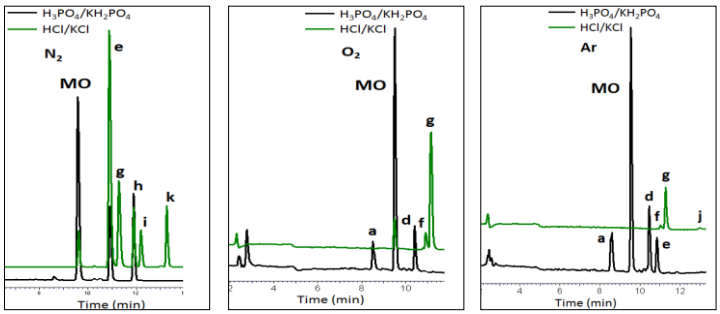
In organic molecules non-thermal degradation, it is known that the gas atmosphere used to generate plasma influences the plasma chemistry regarding the active species produced as well as degradation reactions and, consequently, the byproducts production.[1,2] However, besides the influence from different gas phases, the chemical composition of aqueous phase where non-thermal plasma is applied could also influence and drive certain degradation reactions according to the active species and solution content identities. The present study investigates the influence of different buffer compositions (HCl/KCl and H_3PO_4/KH_2PO_4) and different pH values (2 and 7) on the degradation of Methyl Orange (MO) dye solution (10 mg L^{-1}) by spark discharge non-thermal plasma. The main analytical techniques employed to monitor the decay of MO and the formation of intermediates and products were: UV-Vis spectrophotometry for monitoring decolorization; HPLC-UV/VIS and HPLC-MS/MS for byproducts identification and FT-IR for CO_2 quantification. Previous results presented below show the influence of buffer composition on the byproducts production during the MO degradation (pH 2) using different feed gases to generate plasma: N_2, O_2 and Ar.



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Simulation of the fluid dynamics in a swirl-stabilized and plasma assisted burner

P-15

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Plasma assisted combustion emerged in recent years as an important technological tool for pollution control and flame stabilization under lean or rich conditions. In this work, it was used a computational fluid dynamics simulation to study a burner configuration that couples a plasma torch chamber in a typical swirl burner. In this case, the plasma torch was used to assist the pre-burning of the mixture feeding the main flame. Using Large-Eddy-Simulation (LES), it was modelled the swirl driven turbulent compressible flow. A complete description of the hydrodynamic quantities in the non-reacting case was obtained, focusing in the mixing dynamics of the fuel-air mixture. It was also modelled the reacting flow considering an effective set of transport parameters (diffusion coefficient, thermal conductivity and viscosity) and an effective reaction scheme for methane combustion. The species from the plasma reactor were introduced in the main flow as a boundary condition in the reactor's outlet, whose composition was estimated assuming plasma at thermal equilibrium. The temperature was experimentally estimated using the molecular emission spectra from the plasma. The results gave the scenario of the flame properties prior to a plasma combustion experiment, yielding the most promising conditions for the operation of the swirl-stabilized burner.

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The influence of hydrogen peroxide in the discoloration reaction of the dyes red phenol and indigo carmine employing a non thermal plasma reactor

P-16

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The reaction environment provided from the non thermal plasma is the sum of physicals, chemical and synergetic events, where various elementary chemical reactions can occur simultaneously, however the oxidations reactions are prevalent [1]. The non thermal plasma generated in the water surface with the influence of the gas environment can originate active and oxidant species. Among the most common species, we have the peroxide hydrogen and the hydroxyl radical [2,3], from the reactions 1 at 3.

$H_2O + e^- \rightarrow OH^\bullet + H^\bullet$ (1)

$OH^\bullet + OH^\bullet \rightarrow H_2O_2$ (2)

$H_2O_2 + h\nu \rightarrow 2OH^\bullet$ (3)

When in water, those species can oxidize most organic mocelulas, for example, dyes [2,3,4]. The efficiency of the oxidation reaction is relative to oxidative potential of each species. The peroxide hydrogen is a relative strong oxidant (E° = 1,77 eV), but lower than the hydroxyl radical (E° = 2,8 eV) [2,3]. The identity working gas is crucial to the compositional characteristic of the active species in the plasma [4]. When we used nitrogen gas, nitrogen species was formed, like nitrite (NO_2), and nitrate (NO_3), among others [2]. This way, the hydrogen peroxide can react with nitrite, forming the peroxynitrite anion. The peroxynitrous acid can create through the protonation peroxynitrite anion in acid pH, both species are important, with oxidative potential of 2,44eV and 2,04 eV respectively . The present study investigated the hydrogen peroxide influence and its products in the discoloration reactions of the phenol red (PR) and indigo carmine (CI) dyes, all in aqueous solution. [1] V. Parvulescu, M. Magureanu, P. Lukes. *Plasma chemistry and catalysis in gases and liquids*. 1º ed, p. 100 - 281, 2012.

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The AC rotating gliding arc applied in the propane pyrolysis for gas phase synthesis of carbon black.
P-17

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The hydrocarbon reform is extensively used for gas phase synthesis of carbon black. This process is based on the incomplete combustion, emitting large amount of pollutants. Thus, from the economical and ecological view point, the plasma process provides an interesting alternative for carbon black production[1]. In many cases thermal plasma is used, and has high power consumption. However, the non-thermal plasma process, based on the high voltage and low current, can be applied in the carbon black production [2]. Non-thermal plasma device has been developed and applied in this work for the propane pyrolysis under atmospheric pressure with focus in the carbon black production. The plasma was generated from rotating gliding arc and the products were characterized by X-ray diffraction (XRD), transmission electron microscopy (TEM) and Raman spectroscopy. The solid carbon obtained by this process is like "clumped paper sheet" (Fig. 1).

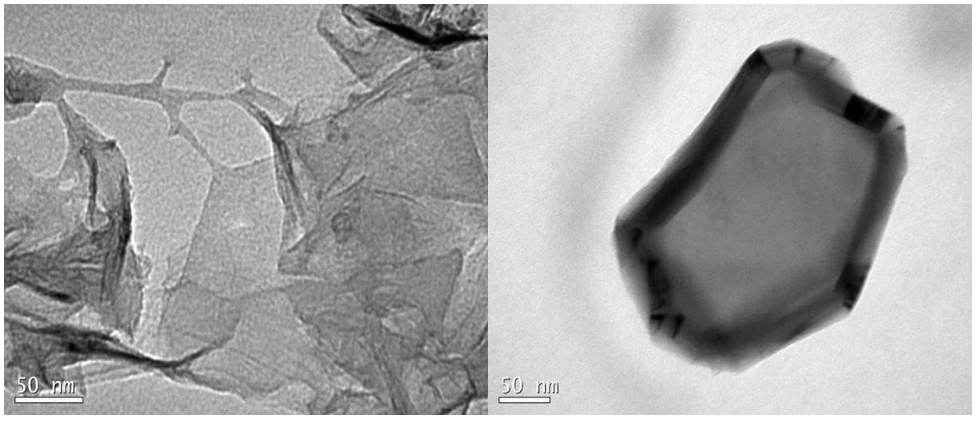

Figure 1 – TEM image of carbon black like "clumped paper sheet".

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Plasma-catalytic reforming of biogas into value-added fuels
P-18

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Dry reforming of biogas (CH_4 and CO_2) has been regarded as a promising and attractive process to produce renewable and value-added fuels and chemicals such as hydrogen. However, in the conventional thermal catalytic reforming of biogas, high reaction temperatures (>700 ^oC) are required to maintain reasonable conversions of reactants and yields of syngas, which incurs a high energy cost. Moreover, the formation of carbon deposition on the catalyst surface causes rapid deactivation of the catalyst, especially for non-noble metal catalysts.

The combination of non-thermal plasma and catalysis offers an attractive and promising alternative to the thermal catalytic route for the conversion of biogas into renewable and value-added fuels and chemicals at low temperatures [1-4]. The non-equilibrium character of such plasma could break thermodynamic equilibrium barrier in conventional thermal processes. Plasma-catalytic processes have great potential to reduce the activation barrier of catalysts, enhance the conversion of reactants and improve selectivity towards the desired products [1, 4]. In this work, plasma-catalytic reforming of biogas over supported Ni catalysts has been investigated in a coaxial dielectric barrier discharge (DBD) reactor at low temperatures (<200 ^oC). The effect of catalyst supports on the reaction performance have been investigated in terms of the conversions of reactants, the yield and selectivity of target products, and the energy cost and the fuel production efficiency of the plasma process.

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How does N_2 influence the dry reforming of methane in a dielectric barrier discharge: a combined experimental and computational study

P-19

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Dry reforming of methane (DRM) and CO2 splitting are considered a hot topic both from an economic and ecological point of view. So it is not surprising that a lot of research effort has already been put into non-thermal atmospheric plasmas for this purpose [1,2,3]. CO2 gas flows from industrial and CCSU/R often contain impurities, of which in most cases N2 is the main component. Furthermore, a lot of research on plasma-based DRM has been performed in diluted N2 streams, without accounting for its effects on their presented results. Therefore, it is of great importance to study the effect of N2 on plasma processes. The following specific questions need to be answered: how does N2 affect the conversion and energy efficiency, and which products (e.g., useful products or harmful NOx compounds) would be formed. Previous work showed that in the case of pure CH4 reforming [4] and pure CO2 splitting [5], the presence of N2 led to unwanted effects, i.e., soot deposition [4] and NOx production [5], respectively. In theory, from a chemical kinetics point of view, this can be explained by the absence of an oxidant and the absence of a hydrogen source, respectively. As such, in theory both unwanted effects should not present themselves for the DRM process and N2 might have a beneficial effect. Therefore, the effect of N2 on the DRM process was investigated for a dielectric barrier discharge by a combined study of experiments and simulations [6].

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Acid/Base Catalysis of Phenol Degradation by Non-Thermal Plasma Discharge
P-20; O-8

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Hormones, drugs and pesticides are among the most feared contaminants by the scientific community because its accumulation in living organisms, leading to a chain of environmental problems.[1] The use of non-thermal plasma (NTP) discharges for the abatement of aqueous matrices of those organic pollutants has been widely studied. In this scenario, oxygen plasma can induce the formation of primary (e.g, radicals) and secondary species (e.g. H_2O_2, O_3) as well as other reactive oxygen species responsible for degradation of organic matter through successive oxidation reactions.[2] It is known that phenol OH-adduct and hydroxyl radicals spontaneously undergo acidic or basic catalysis, lacking water to give the phenoxyl radical which is stabilized by resonance.[3] However, the current work of the NTP research field ignores the contribution of specific and general acid/base catalysis on the degradation of organic compounds, leaving a gap of information to be studied. The main aim of this work is to show the contribution of acid/base catalysis in phenol degradation, chosen as a model molecule. The tests were conducted in an oxygen atmosphere where the NTP discharge was generated above a set of phenol solutions prepared in different aqueous buffers (inside the pH range of 3 to 12) and of different buffering capacities in order to established the role of general and specific acid/base catalysis on the degradation of phenol by O_2-NTP.

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Synthesis of high purity silicon carbide by non transferred arc thermal plasma.

P-21

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The abrasive property of silicon carbide is widely used due to its high hardness and high mechanical and thermal resistance. Allied to this, the semiconducting properties of ultrapure silicon carbide enable it to be used as a strong candidate for the raw material usable in the electronic microprocessor industry and micromechanical devices, able to operate in extreme environments. In the Acheson process, there are different routes for the synthesis of silicon carbide. Recently emphasis has been given to the use of reactors thermal plasma technology as an alternative use for this purpose considering the extremely high temperatures achieved by this process. This paper aims to silicon carbide synthesis of ultrapure silicon by non transferred arc thermal plasma technology. Silicon was extracted from rice hulls and ultrapure carbon obtained by pyrolysis of methane in thermal plasma reactor. The homogenous mixture of carbon and silicon was transferred to a ceramic platform and positioned at the base of the plasma jet in the plasma reactor in which the reaction occurred. The analysis of the product was performed by X-ray diffraction Measurements were obtained by the powder method, Philips X'Pert diffractometer with Cu Ka1 radiation, λ 1.5406 Å. Three layers were identified in the samples. Moissanite, Cristobalite and tridymite. The phase moissanite 3 / ITC / RG syn corresponds to the chemical formula SiC confirming the product synthesized by the proposed method.

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Coupling of non-thermal plasma and biosorption onto *Baillonella Toxisperma* for the disposal of Red Remazol B in water

P-22

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Non thermal plasma with humid air as feeding gas was coupled to an abundant biomass waste (biosorbant) for the optimal removal of Red Remazol B (RR_B) in water. The rate of decolourization reached 60% after 90 min of exposure compare to 39.6% and 11.2% for simple biosorption and conventional plasma treatment. Furthermore, 16.72% of COT reduction was obtained compare to 3.4% with plasma treatment alone. The FTIR spectra of raw material, material after biosorption and biosorbent issued from coupling method show that, the RR_B molecules fixed on the biosorbent by adsorption were more easily oxidized by plasma species. The UV-Vis spectra of the three treatments above mentioned confirm that the synergic action of non-thermal plasma and biosorption is most efficient and can therefore be a green alternative to improve the efficacy of plasma disposal of recalcitrant pollutants in water.

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The DBD plasma applied to control liquid transport for µPADs
P-23

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The hydrophobic/hydrophilic modification of materials like paper allows the expansion of its application in new areas, like the development of microfluidic paper-based analytical devices (µPADs)[1][2][3]. This study investigates the modification of hydrophobic/hydrophilic character of paper with DBD plasma and its application at the development of µPADs.

The discharges were generated between tip-plan electrodes with power rating of 43.6 W. The sulfite, kraft-line and duplex papers were treated with plasma: Argon, O_2, N_2, air and R407C. Changes in the hydrophilicity were observed (**Figure 1 B**) through contact angle analysis.

The **Figure (1 A)** shows the results of a drop of aqueous solution (NaOH, 0.1 mol L^{-1}, 20 µL) on air plasma treated sulfite paper soak with Phenolphthalein indicator solution. It can be seeing from Fig. 1 Aa, the wettability were much larger on treated paper than on the untreated one. Therefore, plasma treatment can be an alternative form to the control of liquid transport for µPADs.

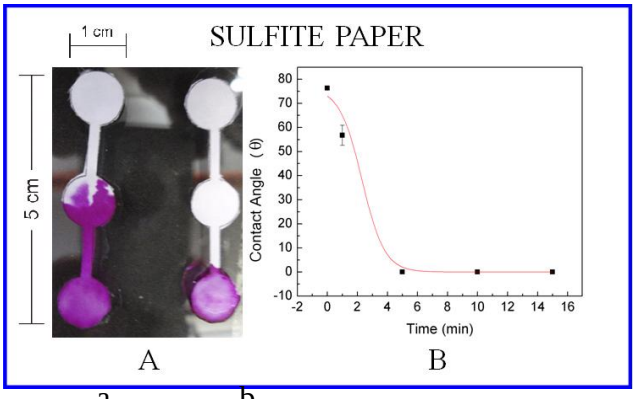

Figure 1. Two sulfite papers shaped like µPADs, treated and untreated by atmospheric air plasma, respectively (**A**) and, graphic of the contact angle against time of treatment (**B**).

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Temperature effect on the formation of Ti_2O_3 in magnetron sputter deposition
P-24

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Thin film deposition is a way to change the surface properties of a piece without changing the bulk properties. Among the most used plasma techniques for film deposition, stands out the magnetron sputtering and its modifications like the grid assisted magnetron sputtering [1]. Titanium dioxide thin films have attracted great attention of scientific community due a wide range of applications of their different crystalline phases: anatase (A) and rutile (R) [2]. Other titanium oxides, like Ti_2O_3, are also of technological interest [3].

To verify how the substrate temperature affects the formation of titanium oxides, several depositions were realized changing the temperature from 100 ^oC to 400 ^oC. Depositions without external heating were also made. The films were deposited on glass substrates. The discharge power was fixed in 470 W and the grid-to-target distance in 2.0 cm. The substrates were biased to - 200 V at 5 kHz. All the depositions were realized just before the first critical point of the hysteresis curve [4], i.e. with the all the O_2 inserted in the reactor being consumed. The films were analyzed by measurements of contact angle (before and after exposure to UV radiation - 253.7 nm) with deionized water and with diiodomethane. The analysis by grazing incidence X-ray diffraction (GIXRD) shows the presence of the planes: Ti_2O_3 (012), A (011), R (110), Ti_2O_3 (104), A (112), R (111), Ti_2O_3 (202), Ti_2O_3 (024), Ti_2O_3 (116) and Ti_2O_3 (211).

For low temperature (without external heating and 100 ^oC) the spectrum is dominated by A (112) and R (111) peaks. With increased temperature an increase in Ti_2O_3 (202), Ti_2O_3 (104), R (111), Ti_2O_3 (116), Ti_2O_3 (211), Ti_2O_3 (012), R (110) and A (011) peaks are observed. The spectra clearly show that for higher temperatures the most intense peaks are related to Ti_2O_3. The plane Ti_2O_3 (024) is observed only for 400 ^oC. The increase in Ti_2O_3 peaks with temperature can be attributed to the increased oxygen desorption from film surface during deposition, although a deeper investigation is necessary to confirm this hypothesis.

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Niobium doped titanium oxide thin films: optical transparent and electrical conductive oxide (TCO)

P-25

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Titanium oxide films doped with niobium were deposited by sputtering, using triode magnetron sputtering technique. Films containing different ratios of Nb/Ti, and deposited under different substrate bias (DC and pulsed modes), were characterized by the following techniques: atomic force microscopy, x-ray diffraction (XRD), energy dispersive fluorescence of x-ray (EDX) and contact angle. In the XRD pattern only Ti_xO_y phases was found, indicating that the Nb atoms are substitutional atoms in sites of Ti. The contact angle is used to indirectly access the photocatalytic efficiency. The hydrophilicity of the samples were evaluated before and after ultraviolet (UV) exposure and results show that films produced with higher Nb/Ti ratio, and in the pulsed polarization bias, that favors a more intense bombardment, reduces the contact angle producing hydrophilic films. The dominant factor for this observation is the oxygen vacancies arising from the Ti_xO_y phase. The electrons photo-generated can reduce Ti^{4+} cations for Ti^{3+} state while the holes act to oxidize O^{2-} anions. In this process, the oxygen vacancies are created at the surface, and promote the adsorption of OH groups [1], [2]. Charge carriers in the film surface produce in contact with water and oxygen molecules, hydroxyl radicals and superoxides. These highly reactive species can promote the decomposition of various organic molecules on the surface of Ti_xO_y [1], [2], [3].

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Selective Hydrogen Production by Non Thermal Plasma Processing of Residual Heavy Oil
P-26, O-15

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The predominant chemical reactions conducted in a cold plasma reactor are essentially dehydrogenations when hydrocarbons are the reactive. Taking advantage of this characteristic, the present study is focused on the production of hydrogen from residual heavy oil, using argon as carrier gas. The main goal is to consider the process as an alternative method for production of a gas rich in hydrogen and free of carbon monoxide.

The present paper analyzes the production of hydrogen when a residual heavy oil is processed in nonthermal plasma chemical reactors. The products distribution exhibited high concentration of hydrogen as a consequence of light olefins production. The high concentrations of olefin compounds of low molecular weight can be drawn taking into account that dehydrogenation is a common reaction occurring in plasmas.

The main goal is to consider the process as an alternative method for production of a gas rich in hydrogen and free of carbon monoxide. Furthermore, light olefin hydrocarbons such as ethylene and propylene are commonly employed as additives in the NOx removal conversion systems for power plants and vehicles exhaust gases. The present research was initiated in the Department of Ecological Engineering, Toyohashi University of Technology, Japan, in 1998 with the purpose to investigate a nonthermal plasma plate-to-plate reactor to convert a residual heavy oil (high molecular weight hydrocarbons, essentially paraffins in the range of n-C10 to n-C25, into light hydrocarbons (mainly olefins) to be employed, for example, as gasoline components for the new generation of engines in the so-called “hybrid process”; or to be added in small amounts to certain catalytic processes for reduction of nitrous oxides compounds in the power plants and vehicles exhaust gas treatments.

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Mercury Removal From Solid Waste By Reactive Plasma And Thermal Disorption Processes

P-27

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Diatomite (SiO_2_nH_2O) or diatomaceous earth consists of a highly porous structure, low density and high surface area resulted in a number of industrial applications as filtration media for various beverages and inorganic and organic chemicals as well as an adsorbent for per liter and oil spills [1]. The present studies was focused on mercury removal from diatomite sorbent samples with mercury content about 24 g/kg obtained from industrial electrochemical production of chlorine and sodium hydroxide from brine using mercury electrodes. The experiments were performed in an oxygen hollow cathode discharge (HCD) at pressure range of (36 – 80) Pa. The discharge voltage was varied in the range of (1000 – 1500) V corresponding to discharge direct currents between 1.0 A and 2.0 A. Thermal desorption and plasma oxidation was performed at reduced pressures to lower the boiling point of mercury and to enhance the kinetics process yield, in turn allowing the unit to be operated at a lower temperature and exposure time with reduced emissions of process gaseous. Under these conditions, the HCD effects and exothermic reactions change the wall temperature of the hollow cathode in the range of (673-773) K. The results show a considerable acceleration of the diatomite decontamination to temperatures above 673 K, reaching concentration of mercury below 100 ppm with exposure times of the order of 10 min. The Hg contamination in the regions near the reactor and exhaust points is smaller than 1 μg Hg/m³ of air.

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Polymerization of maleic anhydride films assisted by plasma

P-28

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Plasma polymerization is a method to produce thin film polymer onto surfaces and it´s a solventless technique [1]. This kind of film deposition aims to transform monomers with functional groups on polymeric films. These functional groups can act as anchor points for chemical reactions and catalysis [2-5]. The use of plasma (Ar + MA) for film deposition of maleic anhydride (MA) shows a suitable process for growth films with nanometric thickness. Plasma polymerization of MA was carried out in a homemade reactor with asymmetric electrodes, onto glass substrate, under continuous and pulsed discharge and also using cathodic cage. Samples were characterized by Fourier transform infrared (FTIR) spectroscopy, water contact angle and atomic force microscope (AFM). It was evaluated the influence of plasma cathode geometry and electrical pulses mode of power supply on the film thickness and its morphology, besides on structure of the deposited film. Films deposited in pulsed plasma did not show peaks of MA in FITR spectra while the MA structure was more preserved in films deposited through DC plasma. The drop water contact angle show results as low as 10^{o} which denotes a super hydrophilic surface.

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Decomposition of dichloromethane by dielectric barrier discharge non thermal plasma reactor

P-29

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Dielectric Barrier Discharge (DBD) is a specific type of alternating current discharge, used to generate non-thermal plasma at atmospheric pressure and moderate temperature and is considered an adequate system for treating chlorinated pollutants[1, 3, 5]. The organochlorine compounds are widely used in industry as solvents, and are chemically persistent and may be carcinogenic and or teratogenic agents[1, 4, 6]. The experiments were performed in non-thermal plasma DBD reactor, combining ozonation processes and ultraviolet photolysis[1, 5]. In this study, 3mL of dichloromethane (CH_2Cl_2) were placed in vial and the vapor phase was carried to the discharge region of the plasma using dry atmospheric air (0.2 to 1.5 $L.min^{-1}$). The power supply (12 kV) was connected to the reactor and an oscilloscope were used to measure the voltage and current. The discharge time used in all experiments was 10 minutes. The results evaluated were the CH_2Cl_2 decomposition and the byproducts generated by the DBD. The analyses were performed by gas chromatography with flame ionization detection (GC-FID). The chromatographic analysis showed degradation exceeding 99% and the mass spectrometry showed the formation of acetic acid, trichloromethane and trichloronitromethane as the preferential byproducts.

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Plasma sterilization of HDPE polymer through N_2-O_2 RF discharge.

P-30

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Plasma sterilization techniques present effective and extensive microbial lethality, fast action, compatibility with various materials, high diffusion through porous substances and are non-polluting systems [1]. The advantage of using the inductive RF plasma (ICP - *Inductively Coupled Plasma*) is the larger volume of the glow region without requiring the use of electrodes inside the chamber [2]. Rf discharges may produce intense energetic photons (UV-A) and higher density of radicals, enabling sterilization by all sides of the piece [3]. In this work it was studied the sterilization of thermoplastic polymer high density polyethylene (HDPE) samples in N_2-O_2 plasma. Nitrogen and oxygen (N_2-O_2) are non-polluting gases and plasma N_2/O_2 is noted for sterilizing efficacy [4]. The experimental apparatus used in this work consists of a tubular tube of quartz with a coil around the tube wall and connected to a RF source. The active species formed in plasma are identified by a system of optical emission spectroscopy (OES). Modifications on the samples surfaces were analyzed through various techniques, such as: atomic force microscope (AFM), superficial roughness, scanning electron microscopy (FEG-SEM), Fourier transform infrared (FTIR) spectroscopy and contact angle. For the sterilizing effectiveness test, it is used *Geobacillus stearothermophilus* spores with a standard load $1x10^6$ UFC/support.

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Polysort functionalization of LDPE by exposition on medium pres sure treatment of DBD non thermal plasma

P-31

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Polymeric materials are extremely versatile and they have wide use on several technological areas. However specific characteristics of surfaces may aggregate value to the simplest commodities. This work presents preliminary results of multivariate insertion of functional groups at the surface of low density polyethylene (LDPE) by discharge of non thermal plasma using halogenated solvent in vapor phase and common gases in synthesis, Fig. 1. The X-ray Photoelectron Spectroscopy (XPS) analysis was performed on the samples, to verify the oxidation state and the presence of oxygen as water, before and after melting the polymer pellets. The infrared (FTIR-ATR) analysis showed that the main groups inserted in polymer matrix was similar when using O_2 or N_2, although functionalization has started at different times. The presence of CCl_4 vapors did not promote the incorporation of groups but began some crosslinking in the upper layers of the sample. Finally, despite ionization energies may be similar, the way in which molecules are inserted into the reaction environment may limit the availability and its subsequent insertion.

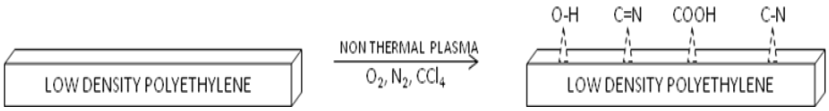

Figure 1. Schematic drawing of the desired modifications.

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Thermal Plasma Application for Treatment of Sludge Leachate
P-32

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The disposal of municipal waste in landfills is the technique most commonly employed for the remediation of solid residues. The residues undergo decomposition beneath the soil and in the presence of water this generates leachate, which percolates down to the bottom of the landfill through drainage. This drained liquid is collected from the landfill installations and subjected to treatment. In this context, a method for the treatment of sludge originating from the physicochemical remediation of leachate using thermal plasma is proposed in this paper. The inerting was carried out in a plasma reactor with a transferred arc torch. The reactor consists of a cathode and a graphite anode. The whole system was placed inside a furnace with an opening for the collection of gases.

The efficiency of the method was verified by monitoring the total organic carbon content, water content and density of the sludge. The quantity of metals present in the samples was determined before and after pyrolysis by thermal plasma using flame atomic absorption spectroscopy (FAAS), scanning electron microscopy (SEM) and X-ray fluorescence (XRF) spectrometry techniques. The results of mass reduction show that for samples with higher quantities of sand, the mass reduction is lower, because the silicate being responsible for the vitrification of the samples. The results from atomic absorption spectrometry analysis show that there was a greater volatilization of metals for the sample with a 1:1 sand to sludge ratio. Through the SEM analysis, a reduction in C, O, CI and Mg after the thermal plasma treatment can be observed. The results obtained with the XRF spectroscopy shows that the elements which have the greatest reductions were Ca (2.98%), Al (1.42%), Cl (0.82%), Mg (0.62%), K (0.29%) and Fe (0.15%).

The results show that the sludge treatment method used was efficient, demonstrating 100% efficacy. In this regard, the best results were obtained for the samples of iron and sample of zinc.

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Monosort functionalization and derivatization of polypropylene surface by non thermal plasma

P-33

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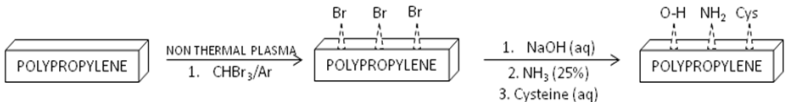
Polymeric materials are extremely versatile and they have wide use in several technological areas. However, specific characteristics of surfaces may add value to the simplest commodities. This work presents results on multivariate insertion of functional groups at the surface of polypropylene (PP) by discharge of non thermal plasma using a halogenated solvent in vapor phase and argon as a background gas, Fig. 1. The X-ray Photoelectron Spectroscopy (XPS) analysis showed that the plasma exposure time has stronger dependence on the concentration of groups anchored on the surface than the power supplied to the plasma discharge. Peaks of Br ($3d_{5/2}$) near from 68.5 eV suggests that C-Br were promoted and their concentration at the surface reaches up to 9.2%. Furthermore, the subsequent functionalization showed that halogenated species can be replaced by groups under alkaline medium, although with some selectivity. Atomic force microscopy (AFM) and contact angle was performed to evaluate the profile of roughness and etching caused by the exposure of samples to the discharge. Plasma characteristics, such as the discharge power, working pressure and the amount of impurities in the background gas are crucial to obtain monosort functionalized surfaces.



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Analysis of dominant effect caused by plasma irradiation on inactivation of viruses
P-34

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In order to analyze inactivation process of viruses caused by plasma irradiation, bacteriophages λ and ϕX174 were studied. These bacteriophages have a simple structure consisting of only coat proteins and DNA. Because the coat proteins and the DNA of these bacteriophages can be analyzed separately, quantitative analysis of the damages given to the coat proteins and the DNA is possible.

Experimental results suggested that both coat proteins and DNA were damaged when wet λ phage and wet ϕX174 phage were exposed to discharge plasma. It was found that damage given to the coat proteins was fatal for both λ phage and ϕX174 phage.

Keywords—Bacteriophage, λ phage, ϕX174 phage, dielectric barrier discharge, inactivation

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Methylene blue degradation by non-thermal plasma in the presence of sulphide minerals: primary insights about homogeneous and heterogeneous catalysis

P-35

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Innumerous studies have shown that the non-thermal plasma (NTP) process is a highly efficient tool for the degradation of organic compounds in liquid phase [1][2]. Combination of NTP discharge with minerals, such as pyrite (FeS_2), was previously studied [3][4] and has been shown to be a very interesting way to enhanced organic matter mineralization from aqueous phase and potentially decreasing energy costs. However, it is worthy to say that the combination effect of sulphide minerals and NTP in order to degrade dyes is not well understood until the present and have motivated this work. On the one hand, pyrite (FeS_2) and pyrrhotite (FeS) in an aqueous environment release Fe^{2+} ions that undergo oxidation in contact with hydrogen peroxide (H_2O_2) produced by the plasma, leading to increased production of hydroxyl radical (·OH), the main oxidizing agent of advanced oxidation processes, which acts in the degradation of dyes [3]. On the other hand, primary and secondary plasma species as well as dye molecules may be involved in surface reactions taking place on the gas/solid and/or liquid/solid interface of the minerals, as already observed in classical heterogeneous catalysis. Whether heterogeneous or homogeneous catalysis are the main responsible for dye degradation is already unknown.

In this work we report the effect of soluble (Fe^{2+} salts) and insoluble (FeS_2 and FeS) iron sources on the pH, ionic conductivity, H_2O_2 concentration, and methylene blue dye removal. Some insights about homogeneous and heterogeneous catalysis are presented in order to address the main reaction pathways of combined NTP/catalyst system.

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