

Abstracts of
The 1st Asian Symposium for Building
Future of Plasma (1st ASBFP)

Ammonia synthesis using atmospheric pressure fluidized bed plasma

Shungo Zen*,

*Department of Electrical Engineering and Electronic College of Science and Engineering,
Aoyama Gakuin University, Japan*

*E-mail address: zen@ee.aoyama.ac.jp

Keywords: (Ammonia synthesis, plasma catalysis, fluidized bed, dielectric barrier discharge)

In recent years, extensive research has been conducted on ammonia synthesis using catalysts under mild conditions and by combining plasma with the catalysts. Increasing the contact area between the catalyst surface and atmospheric pressure dielectric barrier discharge (DBD) is crucial for improving the ammonia synthesis efficiency. In this study, we present a fluidized bed plasma that can be used to form a fluidized bed plasma through the electrohydrodynamics of DBD discharge without feed gas. A photograph of the atmospheric pressure fluidized bed plasma is shown in Figure 1. It can be seen that catalyst particles are scattered inside the reactor and a uniform discharge is observed. As a result, the contact area between the catalyst surface and the plasma inside the atmospheric pressure fluidized bed plasma is considered to increase dramatically. We performed ammonia synthesis experiments using a fluidized bed plasma reactor, the results indicate that the fluidized bed plasma can achieve higher energy yields than conventional DBD plasma.



Figure1. A photograph of atmospheric pressure fluidized bed plasma

Plasma-induced Eley-Rideal reaction: Promotion of low-temperature CO₂ methanation

Dae-Yeong Kim^{1*}, Shinya Furukawa² and Tomohiro Nozaki¹

¹*Department of Mechanical Engineering, Tokyo Institute of Technology, Tokyo 152-8550, Japan*

²*Division of Applied Chemistry, Osaka University Osaka 565-0871, Japan*

*E-mail address: kim.d.as@m.titech.ac.jp

Keywords: Plasma catalysis, Non-thermal plasma, CO₂ methanation, atomic hydrogen, Eley-Rideal reaction.

Combining non-thermal plasma (NTP) with catalysis, known as plasma catalysis, is a rapidly growing field as a promising technology for the valorization of CO₂.^{1,2} NTP is generated by electricity, and the applied electrical energy heats electrons. The high-energy electrons generate excited species, ions, and radicals through inelastic collisions with gas molecules. These reactive species react on the catalyst surface, yielding a thermodynamically limited reaction. However, due to the complexity of plasma catalysis, understanding the interaction between plasma and catalysts and reaction mechanisms is still in its early stages.

Here, our goal is to demonstrate the promotion of low-temperature CO₂ methanation ($\text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}$; $\Delta H_{298\text{K}} = -165 \text{ kJ/mol}$) performance over Ni/Al₂O₃ catalyst under NTP conditions compared to thermal conditions. We elucidated the reaction mechanism using kinetic study, in situ infrared absorption spectroscopy, and DFT calculations. The results revealed that plasma-derived atomic hydrogen (PDAH) is the key in promoting the reaction. Under thermal conditions, the reaction proceeds via the Langmuir-Hinshelwood pathway. On the other hand, under NTP conditions, PDAH creates the Eley-Rideal pathway, effectively lowering the energy barrier for CH₄ formation, and thus promoting low-temperature CO₂ methanation.

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Investigation of optimal applied voltage on the wind power generation system using electrospray method

Daichi Obata

Department of Creative Engineering, National Institute of Technology, Kitakyushu College, Japan

E-mail address: obatad@kct.ac.jp

Keywords: wind power generation, electrospray, EHD spray

It is well-known that the conventional wind power generation system using wind turbine has limited range of the wind speed. It means that the conventional system is not suitable for use in area with large wind speed fluctuation. Actually, while capacity factor for offshore wind power generation in Europe is around 55%, it is around 35% even in Hokkaido which has relatively good wind conditions in Japan. Therefore, we focused on the alternative wind power generation system using electrospray method. In the system, the wind carries away unipolar charged droplets supplied by electrospray against coulomb force. The system theoretically has no limit for wind speed because not used moving parts like a wind turbine. However, reported energy conversion efficiency of the system is around 7%, which is much lower than the conventional system.

In this study, we elucidated the effects of applied voltage analytically and experimentally to improve the energy conversion efficiency of the system. The subsequent theoretical analysis is based on the assumption of Stokes flow under a uniform electrical field. The generated power is calculated by the product of the amount of charge between the parallel electrodes, the droplet velocity, and the electrical field. The amount of charge is calculated from the spray current and the droplet velocity. The analytical solution indicates that the generated power is proportional to the applied voltage and the square root of the supplied flow rate. Note that the coulomb force is limited to less than the drag force, and the threshold value of the applied voltage is proportional to the wind speed. In the experiment, a high voltage was applied between the nozzle and a ring-shaped counter electrode, and unipolar charged droplets were generated using electrospray method. The charged droplets were fed into another parallel mesh electrodes and carried against the electrical field by fan wind. As a result of the experiment, the generated power was roughly proportional to the applied voltage, but deviated from the linear relationship around the threshold value. The results suggest that energy conversion efficiency can be optimized by changing the applied voltage depending on the wind speed.

Ammonia synthesis using water and nitrogen under plasma-catalysis hybrid system

Heesoo Lee*, Hong Jae Kang and Dae Hoon Lee

Semiconductor Manufacturing Research Center, KIMM Institute of Autonomous Manufacturing, Korea Institute of Machinery and Materials (KIMM), Daejeon 34103, Republic of Korea

*E-mail address: hslee89@kimm.re.kr

Keywords: Ammonia, Plasma-catalysis, Water, Nitrogen, Hybrid system

Ammonia (NH_3) is an important industrial chemical with a wide range of applications including use as fertilizer, refrigerant, hydrogen carrier, and a precursor for many other nitrogen containing compounds. Traditionally, ammonia has been produced through the Haber-Bosch process, which combines nitrogen gas with hydrogen gas over an iron catalyst at high temperature and pressure. Therefore, this process requires a lot of energy and money. In addition, Haber-Bosch process has problems such as its significant carbon footprint and greenhouse gas emissions.

In this study, we introduced ammonia synthesis method using nitrogen and water under plasma-catalysis hybrid system. First, water and nitrogen reacted to make nitric oxide (NO) and hydrogen utilizing arc plasma in this system. We tried to produce more nitric oxide and hydrogen under same power consumption by applying various types of plasma reactor. Products other than nitric oxide and hydrogen were not detected. Then, nitric oxide was reduced to ammonia under catalytic condition. By this system, we believe that ammonia synthesis process can be improved in terms of economy and environment.

Analysis of Electron-Energy Loss Mechanism in Electron Collision Processes in Hot Gas for Development of Insulation Gases

Naoto Kodama^{1*}, Yasunobu Yokomizu¹, Kanata Nakamura¹, Takuya Igarashi¹

¹Nagoya University

*E-mail address: kodama.naoto.n1@f.mail.nagoya-u.ac.jp

Keywords: Arc interruption, Hot gas, Electron Boltzmann equation, Collision cross-sections

Electrical insulation is one of the crucial roles of circuit protection devices such as gas circuit breakers(GCBs) and fuses. Recently, the development of SF₆ alternative insulation gases is strongly desired due to the usage restriction of SF₆. For the development of alternative gas, we also take into account PFAS restriction to develop F-free gas. If we cannot use materials including F-species, we cannot use the strong electron attachment ability of F-species (e.g. F₂, CF₄) to increase the breakdown electric field strength(BEFS) of insulation gases. Thus, we need to find new BEFS rise mechanisms that not use electron attachment of F-species.

To investigate a new BEFS rise mechanism, we theoretically calculated electron-energy distribution function(EEDF) of Cu/SiO₂ vapor mixture through electron Boltzmann equation considering various electron collision processes. The Cu/SiO₂ vapor mixture is hot gas formed in the fuse, and it insulates the fuse after the arc interruption. By using calculated EEDF, we also calculated electron attachment coefficient(η/N) and ionization coefficient(α/N) as a function of Cu concentration and reduced electric field strength(E/N), as shown in Fig.1(a). The present result shows that mixing of high concentrations (e.g., 30%) of Cu vapor significantly decays α/N , and then it raises critical E/N . This rise in critical E/N and decay in α/N arise from the rise in electron energy loss(EEL) due to the electronic excitation process of the Cu atom, as shown in Fig.1(b). Thus, the present result implies that not only the electron attachment process but also the excitation process (and consequent EEL processes) are useful to rise BEFS of the insulation gases.

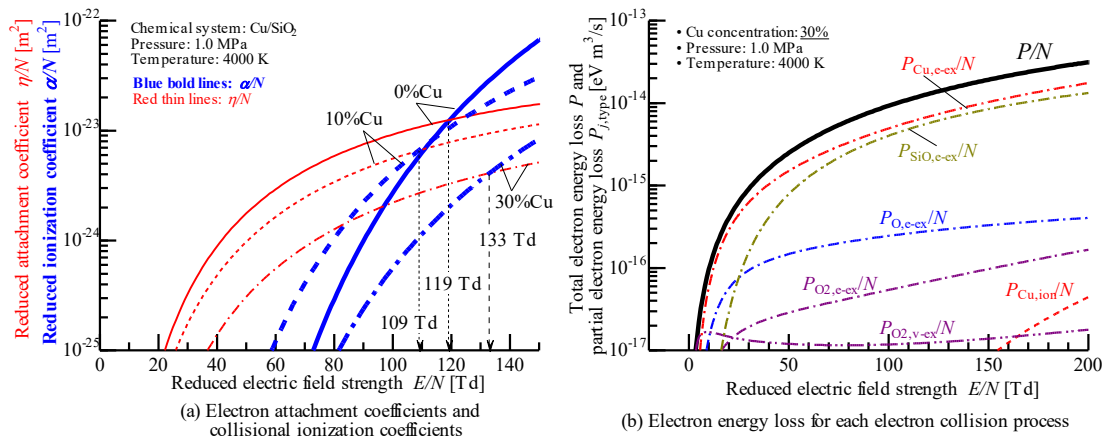


Fig.1 Calculation result of electron attachment coefficients, collisional ionization coefficients, critical reduced electric field strength and electron energy loss of collision process

Developments of Thermal Plasma Generation and Its Applications

Manabu Tanaka^{1*} and Takayuki Watanabe¹

¹*Dept. Chemical Engineering, Faculty of Engineering, Kyushu University*

*E-mail address: mtanaka@chem-eng.kyushu-u.ac.jp

Keywords: dc arc, ac arc, high-speed visualization, nanomaterial, plasma agriculture

Arc fluctuation was successfully visualized by the high-speed camera combined with band-pass filters. Arc plasma is one of the most attractive and convenient high temperature sources. A multiphase AC arc has unique advantages such as large plasma volume, energy efficiency, and low gas velocity. The multiphase AC arc is potentially expected to be utilized as plasma source for plasma agricultural applications like a nitrogen fixation. However, both application-oriented and fundamental-oriented researches such as fluctuation characteristics of the multi arcs are insufficient whereas those are essential for the application to industrial fields. The purpose of current study is to investigate the spatiotemporal characteristics of the multiphase AC arc based on the high-speed visualization system.

The multiphase AC arc was generated under near atmospheric pressure at 20 kW as a typical condition as indicated in Fig. 1. The effects of AC driving frequency, plasma gas composition, and ambient pressure were systematically investigated. Interesting arc instability with omega-shaped structure was successfully visualized. Obtained remarks enable us to understand fundamental phenomena and to control the high temperature plasma region appropriately.

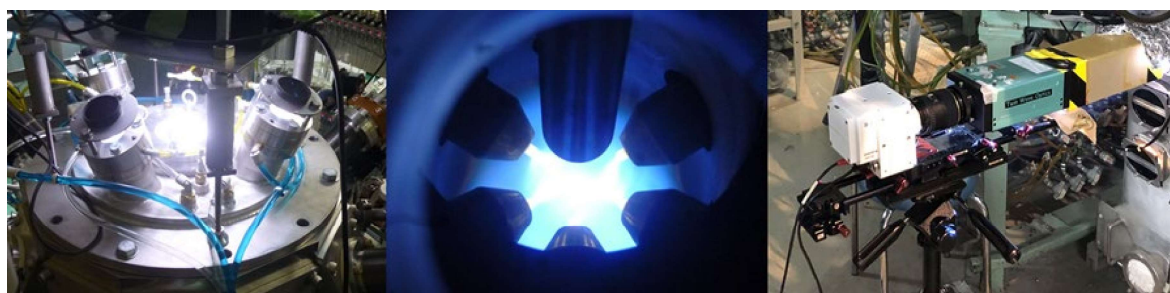


Fig. 1 Representative photographs of arc device and visualization system.

Development process of arc plasma reactor for organic material recycling

Hongjae Kang^{1*}, Subin Choi^{1,2} and Dae Hoon Lee¹

¹Dept. of Plasma Engineering, Korea Institute of Machinery and Materials

²Center for Plasma Process for Organic Material Recycling, Korea Institute of Machinery and Materials

*E-mail address: hjkang@kimm.re.kr

Keywords: Plasma chemistry, Arc discharge, Hydrogen, Rotating arc

The development of hydrocarbon conversion processes based on renewable electric energy has drawn attention from the fields of petrochemical and resource recycling technologies, with the goal of achieving carbon neutrality. A novel recycling process for organic materials is developed in Korea Institute of Machinery and Materials (KIMM) based on hydrogen-based arc discharge. The target of the recycling process is to maximize the conversion and yield of C₂ chemicals (C₂H₂ and C₂H₄) by thermally refining plastic wastes with high-enthalpy H₂/Ar mixture. In the present study, the preceding researches are briefly reviewed and the ongoing development process of H₂/Ar arc plasma reactor in KIMM is introduced.



Figure 1. Operation of rotating arc reactor using H₂/Ar mixture.

Neural Network Techniques for Electromagnetic Field Reconstruction in Ion Radiography

Chun-Sung Jao^{1*}, Yen-Chen Chen², Fuka Nikaido³, Shutaro Kurochi³, Kentaro Sakai⁴, Takumi Minami³, Shogo Isayama⁵, Yao-Li Liu¹, Yuki Abe³, Akira Mizuta⁶, and Yasuhiro Kuramitsu³

¹*National Cheng Kung University, Taiwan*

²*National Applied Research Laboratories, Taiwan*

³*Osaka University, Japan*

⁴*National Institute for Fusion Science, Japan*

⁵*Kyushu University, Japan*

⁶*RIKEN, Japan*

*E-mail address: csjao899@gmail.com

Keywords: high-energy-density plasmas, neural network techniques, ion radiography

In controlled laboratory setups, when lasers interact with solid or gaseous targets, various phenomena such as shock formation, plasma instability, and magnetic reconnection can be observed. Understanding the behavior of electromagnetic fields in plasmas is crucial in these experiments. To measure these fields, scientists utilize a method called ion radiography, also known as proton imaging. High-energy protons are generated from a point-like source and directed through the plasma system. As they travel through the plasma, they interact with electromagnetic fields, causing changes to their paths. When these protons reach a detector, they create an image that reveals the electromagnetic field patterns within the plasma. However, a major challenge in proton imaging techniques is determining the path-integrated electromagnetic fields based on the observed proton fluence. To address this challenge, we aim to use neural network techniques to reconstruct electric and magnetic fields for ion radiography applications. We will present the development plan and recent advancements in this context.

Research on Electrohydrodynamic and Thermal Characteristics of Dielectric-Barrier-Discharge Flow Control Actuator

Hiroyuki Nishida^{1*}, Yuki Ishii¹, Yutaka Kaneko² and Asami Hatamoto³

¹*Tokyo University of Agriculture and Technology*

²*Tohoku University*

³*Aoyama Gakuin University*

*E-mail address: hnishida@cc.tuat.ac.jp

Keywords: Data assimilation, Electrohydrodynamic force, Gas heating, DBD array

The electrohydrodynamic force and gas heating of Dielectric Barrier Discharge (DBD) has received attentions for usage of flow control actuator. It can manipulate air flow around an object on which it is installed, and intensive research efforts have been devoted to many engineering applications such as flow separation suppression, turbulence drag reduction, heat transfer enhancement, de-icing and anti-icing. For characterizing flow control capability, we have conducted research to understand the electrohydrodynamic phenomena and thermal characteristics of DBD device. For thermal characteristics, we derived the similarity law of surface temperature change assuming that the dominant mechanism of surface heating is the heat transfer from the heated air flow, and experimentally verified the law that indicates the normalized surface temperature is a function of the Biot and Fourier numbers. For understanding the electrohydrodynamic phenomena, we propose a methodology using the data assimilation to estimate the electrohydrodynamic force which cannot be directly measured. In the data assimilation, the electrohydrodynamic force can be estimated by the combination of computational fluid dynamics and flow field measurement based on the Bayesian inference. Through numerical experiments, we demonstrated that the methodology could inversely estimate the electrohydrodynamic force field using times-series data of density field with sufficient precision. Future important objective is to investigate a DBD array which recently get much attention as effective device for turbulence drag reduction.

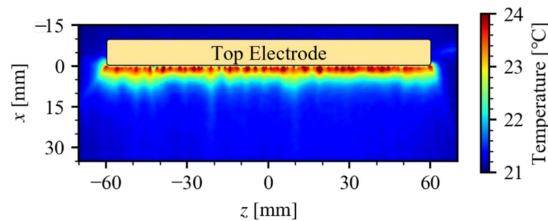


Fig. 1 Surface temperature of DBD

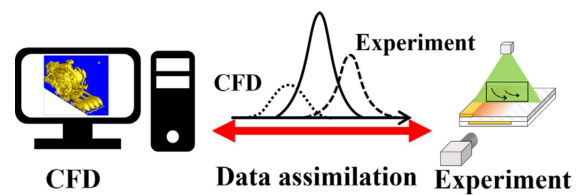


Fig. 2 Schematics of data assimilation

Electrical potential measurement of dielectric barrier discharge and analysis on net electrical field

Atsushi Komuro

National Institute of Advanced Industrial Science and Technology (AIST), Environmental Management Research

Institute, Tsukuba 305-8569, Japan

*E-mail address: komuro.a@aist.go.jp

Keywords: Atmospheric pressure plasma, DBD, Pockels effect, surface streamer,

Dielectric barrier discharge (DBD) is a type of atmospheric non-equilibrium plasma and has been used in some industries such as plasma medicine and materials processing. However, the fundamental process of DBD has not yet been elucidated. When a parallel plate DBD is driven by a sinusoidal voltage under atmospheric pressure, numerous filamentary discharges called microdischarges (MDs) are observed. The surface charge deposited on the dielectric after the discharge plays an important role in the behaviour of these MDs. This study investigates the behaviour of the surface charge density formed by MDs using Pockels sensors. Figure 1 shows the obtained surface charge density distribution at different phases of the applied sinusoidal voltage. The dynamic behaviour of the surface charges is clearly observed, which leads to the further discussion of the physical mechanism of DBD.

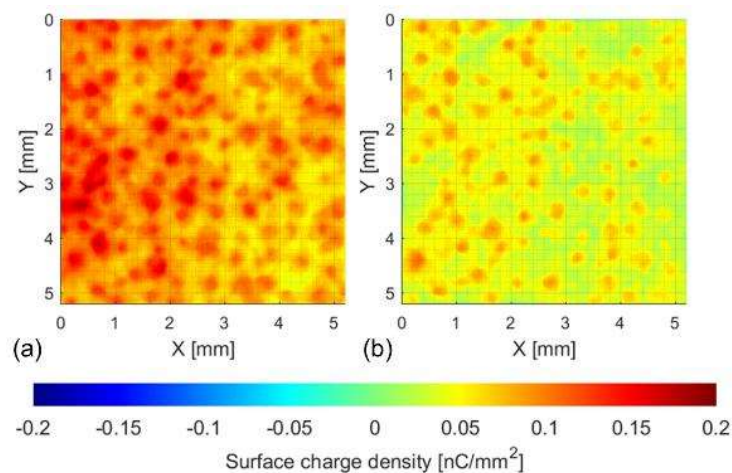


Figure 1: Surface charge distribution on the dielectric surface at different phase of (a) $3\pi/4$ and (b) π rad with 9 kV_{pp}, and 5 kHz. The gap distance of DBD is 0.3 mm at atmospheric pressure air.

A structural Analysis of the Unique Effects of Plasma-Induced Oxidation and Electric Field on Protein Structures

Pankaj Attri^{1*}, Takamasa Okumura¹, Kazunori Koga¹, and Masaharu Shiratani¹

¹ Center of Plasma Nano-interface Engineering, Kyushu University, Fukuoka 819-0395, Japan

*E-mail address: attri.pankaj.486@m.kyushu-u.ac.jp

Keywords: Reactive species, electric field, proteins, low-temperature plasma

In recent years, there has been an increase in the study of the mechanisms behind plasma oncology. For this, many wet lab experiments and computational studies were conducted. Computational studies give an advantage in examining protein structures that are costly to extract in enough amounts to analyze the biophysical properties following plasma treatment [1,2]. We studied the effect of plasma oxidation on proteins like Hsp60, lysozyme, myoglobin, etc. Hsp60, alias chaperonin, is one of the most conserved proteins expressed across all species. We performed molecular dynamic simulations to calculate the root-mean-square deviation (RMSD), root-mean-square fluctuation (RMSF), and solvent-accessible surface area (SASA) with and without oxidation. In addition to the oxidation state, we also applied an electric field to check the changes in the mHsp60 protein. We concluded that the combination of oxidation and electric field effect increases the destabilization of the protein structure compared to their respective control states.

Acknowledgments

This work is supported by JSPS-KAKENHI grant number 22H01212.

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Atmospheric-Pressure Plasma Effects on Cancer Cells and Attempts of Improving Plasma Stability

Yun-Chien Cheng^{1*}

¹Department of Mechanical Engineering, National Yang Ming Chiao Tung University, Taiwan

No.1001, University Road, Hsinchu City 300, Taiwan

*E-mail address: vccheng@gmail.com

Keywords: plasma therapy, thermal therapy, malignant pleural effusion, selective inhibition, machine learning

We compared the effects of plasma with thermal therapy on lung cancer with malignant pleural effusion. This study finds out that the plasma can selectively kill lung cancer cells and the benign cells remain its viability. Besides, thermal therapy kills both cancer cells and benign cells. To investigate what is the plasma factor that inhibits cancer cells, we investigated the effects of plasma-generated short-lived species, long-lived species, and electric fields on skin melanoma and basal cell carcinoma cells (A2058 cells, BCC cells) and normal cells (BJ cells, Detroit 551 cells) and found that the short-lived species do make selective inhibition to the benign and malignant cells. The second part of my study is that we mix water aerosol with plasma jet at downstream region makes the plasma jet generate more $\bullet$ OH. We designed different mixing chambers and adjusting the water aerosol flow rate maximize the $\bullet$ OH generated by plasma jet for biological applications. We also constructed an impedance matching circuit for a partial-discharge calibrated (PDC) atmospheric-pressure plane-to-plane DBD equivalent circuit. The last part of my work is that we used machine learning to distinguish the discharge current of different plasma. The plasma discharge can be different depending on the conditions, and the resulting discharge current has quite different electrical features. Hence, a real-time and cost-effective diagnosis of atmospheric-pressure plasma discharge can be possibly provided via current classification with deep learning model.

Ultrahigh resolution quantum dot patterning for advanced applications

Tae Won Nam^{1*}

¹*School of Materials Science and Engineering, Pusan National University*

*E-mail address: namtaewon@pusan.ac.kr

Keywords: Nanopatterning, Quantum dots

The next-generation wearable near-eye displays inevitably require extremely high pixel density due to significant decrease in the viewing distance. For such denser and smaller pixel arrays, the emissive material must exhibit wider colour gamut so that each of the vast pixels maintains the colour accuracy. Electroluminescent quantum dot light-emitting diodes are promising candidates for such application owing to their highly saturated colour gamuts and other excellent optoelectronic properties. However, previously reported quantum dot patterning technologies have limitations in demonstrating full-colour pixel arrays with submicron feature size, high fidelity, and high post-patterning device performance. Here, we show thermodynamic-driven immersion transfer-printing, which enables patterning and printing of quantum dot arrays in omni-resolution scale; quantum dot arrays from singleparticle resolution to the entire film can be fabricated on diverse surfaces. Red-green-blue quantum dot arrays with unprecedented resolutions up to 368 pixels per degree is demonstrated.

Investigation of several ion mobility and collision cross sections at atmospheric pressures

Yui Okuyama^{1*}

¹*National Institute of Technology, Tomakomai College*

*E-mail address: yokuyama@tomakomai-ct.ac.jp

Keywords: Negative ion mobility, Collision cross sections, Clustered ions, Atmospheric pressures

The fundamental properties of the discharge plasmas such as the mobility, the diffusion coefficients and the collision cross sections have been studied in low pressure gases [1]. Recently, these fundamental data are required also for investigations of atmospheric plasma discharges. At such high-pressures, the negative ion mobility is strongly affected by impurities such as N₂, CO₂ and H₂O because of ion-molecule reactions [2, 3].

The authors investigated the effects of a small amount of H₂O on negative ion mobility in O₂ at atmospheric pressures. As the results, several mobilities of O₄⁻ and O₂⁻·(H₂O)_n (*n* = 1, 2, 3) were estimated by comparison between experimental and simulation data [4].

In this study, obtained several clustered mobility of O₄⁻, O₂⁻·(H₂O), O₂⁻·(H₂O)₂ and O₂⁻·(H₂O)₃[4] were compared with the one calculated by Langevin limits[5]. Then, collision cross sections were calculated for clustered ions O₄⁻, O₂⁻·(H₂O), O₂⁻·(H₂O)₂ and O₂⁻·(H₂O)₃ as by Mason–Schamp’s formula[1]. As the results, it is suggested that the clustered ion mobilities depend on not mass but collision cross sections.

Acknowledgments

This work was supported by JSPS KAKENHI GRANT Number 23K03828.

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Creepage Discharge Observation using Multi-Array Coaxial Probe

Tomohiro Kawashima^{1*}, Soshiro Murata¹, Yoshinobu Murakami¹ and Naohiro Hozumi

¹*Toyohashi University of Technology*

*E-mail address: kawashima.tomohiro.et@tut.jp

Keywords: Creepage discharge, propagation characteristics, multi-array coaxial probe

Optical observation of the discharge shape and propagation speed using a high-speed camera is frequently performed; however, to discuss insulation performance, it is important to quantify the electric field and, therefore, the energy of the discharge. In this study, we constructed a multi-array coaxial probe system and evaluated the propagation characteristics of the creepage discharge from probe potential.

The electrodes with a 5 mm gap were attached to the polyimide surface, and then a positive impulse voltage (20 kV) was applied. A multi-array probe system was constructed in which four coaxial probes were placed along the discharge path, and the potential of the discharge passing directly above the probes was measured.

Fig. 1 shows a schematic diagram of the system and the sample. The coupling capacitance between the probe and the discharge is the largest when the discharge tip comes directly above the probe. At the same time, the probe potential increases rapidly. The increased points of probe potential can be confirmed, as indicated in Fig.2. The time difference between the points implies that the propagation speed slows down as the discharge approaches the ground electrode. Moreover, the discharge should be developed on the step since the potential becomes step-like. These results qualitatively agree with many reports based on optical observation. We will evaluate the discharge propagation at the insulation interface using the developed probe system in our future work.

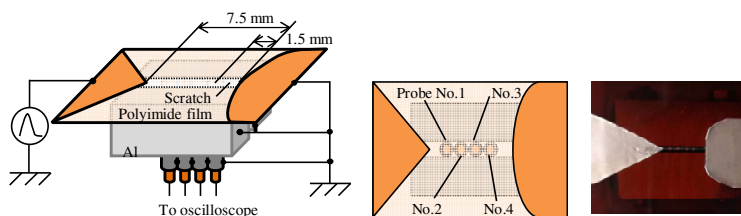


Fig.1 Schematic diagram of probe system and sample

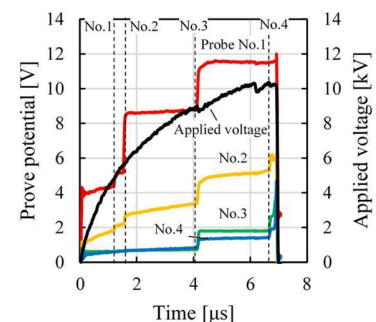


Fig.2 Probe profile

Electrostatic Handling Technologies of the Lunar Regolith for Long-Term Space Explorations

Masato Adachi^{1*}

¹*Kyoto University, Department of Mechanical Engineering and Science*

*E-mail address: masato@me.kyoto-u.ac.jp

Keywords: Lunar Regolith, In-Situ Resource Utilization, Particle Handling, Particle Charging

Regolith particles on the Moon are crucial samples that provide insights into space science. In addition, the regolith also presents two significant challenges that impact the success of future missions: mitigation and utilization. The regolith contains essential components, such as oxygen and hydrogen, which are vital resources for sustaining astronauts' stays on the Moon. On the other hand, small particles can easily adhere to and accumulate on exploration equipment, leading to performance degradation (for instance, dust accumulation on solar panels can prevent light transmission). Therefore, technologies for handling regolith particles have become necessary for both mitigation and utilization, and these technologies must meet the requirements for applications in the harsh space environment. Mechanical and pneumatic technologies have been employed in previous missions. However, these methods have several issues, including dust contamination, short equipment lifetime due to mechanical abrasion, high power consumption, and the need to transport liquid and gas from Earth with extreme care to prevent leakage. As an alternative, electrostatic handling technologies for particles are being considered for space applications. These systems offer several advantages, such as the elimination of unnecessary mechanical drives, gases, and liquids; a simple and light structure; and a negligible power consumption, making them suitable for use in space environments. Electrostatic technologies can handle particles ranging from submicron sizes to several hundred micrometers on Earth, as the balance of forces acting on particles corresponds to the particle size, and the electrostatic force predominates in that range. However, this balance will vary on the Moon due to low gravity and vacuum conditions. Furthermore, the absence of air will also affect the charging states of the regolith particles. Therefore, we have investigated the effects of these space environmental conditions on particle dynamics and applied the insights gained to the development of electrostatic regolith handling technologies. This presentation will provide the overview of the technologies and discuss recent progress.

Simple evaluation method for spray electrification tendency of liquid

Yuta Endo

National Institute of Occupational Safety and Health, Japan

E-mail address: y.endo@s.jniosh.johas.go.jp

Keywords: static electricity, spray electrification, liquid, safety, humidity

The spray electrification that occurs when a liquid spurts out from a nozzle or other piping can cause fires and explosions in chemical plants. Previous studies have shown that the charge of spray electrification depends on individual conditions such as the type of liquid, conductivity of the liquid, material of the nozzle, and pressure applied to the liquid, but the mechanism by which the charge changes has not been systematically understood. Therefore, it is difficult to determine the hazard of spray electrification in advance, and it is necessary to evaluate the hazard through experiments involving the danger of ignition. In this study, we propose a safe and simple method to evaluate the potential hazard of spray electrification for each combination of liquid and nozzle material. In this method, 1 ml of liquid is dropped onto a plate-shaped piece of material, the liquid is instantly blown off with compressed air, and the charge on the piece of material is measured before and after the liquid is blown off. This method simply reproduces the separation of liquid from the surface of a nozzle when the liquid is ejected from the nozzle. The results of measuring the charge for various combinations of liquids and materials using this method showed a similar charging tendency to that measured using an actual nozzle, and it was also confirmed that the charge was equivalent to or greater than that obtained when the nozzle was used. The relationship between the humidity of the surrounding air and the charge was also investigated, and it was confirmed that the charge decreased as the humidity increased. As a result, the proposed method is effective in evaluating the hazard of the spray electrification, and it is necessary to pay attention to the setting of the humidity during measurement.

Evaluation of the correlation between charging characteristics and film quality of polystyrene film

Tomoya Sato^{1*}, Ryo Nakano², Takayuki Miyamae^{2,3} and Kazuya Kikunaga¹

¹National Institute of Advanced Industrial Science and Technology

²Faculty of Engineering, Chiba University

³Molecular Chirality Research Center, Chiba University

*E-mail address: tmy-sato@aist.go.jp

Keywords: Contact electrification, Polystyrene, Surface structure, Sum-frequency-generation

When two substances are brought into contact and subsequently separated, a potential difference is created between the surfaces of the two substances. This phenomenon is called as contact electrification and is widely used in various technologies [1, 2]. However, the influence of the film quality of insulating polymers on the charging properties remains controversial. In this study, therefore, we focused on the film quality of insulating polymer films and evaluated the correlation between the two using polymer films prepared under different conditions.

In this study, polystyrene (PS) films prepared under three different conditions were used as samples: spin-coated films, films annealed at 150 °C for 1 h and films degassed in vacuum for 2 h. The surface structure of each film was investigated using sum frequency generation (SFG) spectroscopy. The charging properties of them were evaluated from the change in surface potential when the surface was negatively charged by corona discharge treatment.

SFG spectra of each PS film are shown in Fig. 1. In the spin-coated and degassed films, peaks originating from the stretching vibration of the phenyl groups were observed around 3060 cm⁻¹, as well as peaks originating from the stretching vibration of the CH₂ and CH₃ groups. In contrast, only a peak derived from the stretching vibration of the phenyl group was observed in the annealed film. These results suggest that PS takes various morphologies on the surfaces of the spin-coated and degassed films, whereas the phenyl groups are preferentially orientated on the surface of the annealed film.

Figure 2 shows the change in surface potential of each film after the corona discharge treatment. As can be seen in Fig. 2, the magnitude and attenuation trend of the surface potential differed depending on the fabrication conditions. In the conference, we will report on the results of a detailed discussion of the correlation between the surface structure of the PS films and the charging characteristics, together with other measurement data.

[1] W.-G. Kim et al., ACS Nano, 15, 258 (2021).

[2] Z. Wang et al., Chem. Soc. Rev., 53, 4349 (2024).

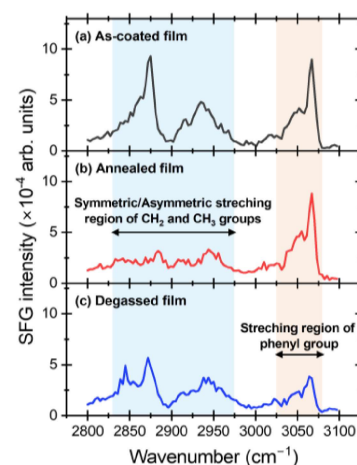


Fig. 1. SFG spectra of (a) as-coated film, (b) annealed film, and (c) degassed film.

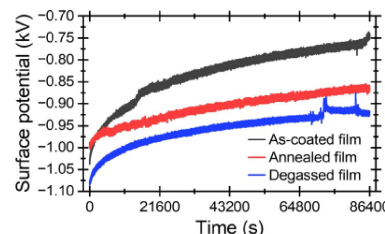


Fig. 2. Change in surface potential of each polystyrene film after corona discharge treatment.

Investigation of argon-plasma-induced post-discharge reactions in dilute sulfuric acid by electron spin resonance method

Kosuke Tachibana^{1*}, Seiji Kanazawa¹, Katsuyuki Takahashi², Junko Hieda³, Nozomi Takeuchi⁴ and Oi Lun Li⁵

¹*Faculty of Science and Technology, Oita University, Japan*

²*Faculty of Science and Engineering, Iwate University, Japan*

³*Graduate School of Engineering, Nagoya University, Japan*

⁴*Department of Electrical and Electronic Engineering, Tokyo Institute of Technology, Japan*

⁵*School of Materials Science and Engineering, Pusan National University, Korea*

*E-mail address: tachibana-kosuke@oita-u.ac.jp

Keywords: plasma in contact with liquid, dilute sulfuric acid, post-discharge reaction, electron spin resonance (ESR)

Catalyst for hydrolysis of cellulose to glucose, which is very important to highly efficient biofuel process, can be efficiently synthesized by plasmas in contact with dilute sulfuric acid (H₂SO₄) [1], but its synthesis mechanism is not fully understood. In this study, to better understand the synthesis mechanism, we investigated what chemical reactions proceeded in dilute H₂SO₄ after argon plasma irradiation through radical measurements using an electron spin resonance (ESR) spectrometer and a spin trapping reagent of CYPMPO. Fig. 1 shows ESR spectrum of 500 mM H₂SO₄ with various post-discharge time when the CYPMPO was added to the 500 mM H₂SO₄ after the argon plasma irradiation. Peaks derived from CYPMPO-OH and unknown spin adducts were observed in the 500 mM H₂SO₄ after the plasma irradiation, and their peak intensities increased with the post-discharge time. This result indicates that chemical reactions, which probably caused by long-lived chemical species, proceed in dilute H₂SO₄ after the argon plasma irradiation is finished.

This work was partially supported by the Environment Research and Technology Development Fund (JPMEERF20223R01) of the Environmental Restoration and Conservation Agency of Japan.

[1] L. Qin, et al., ACS Sustainable Chem. Eng., 2020, 8, 5837–5846.

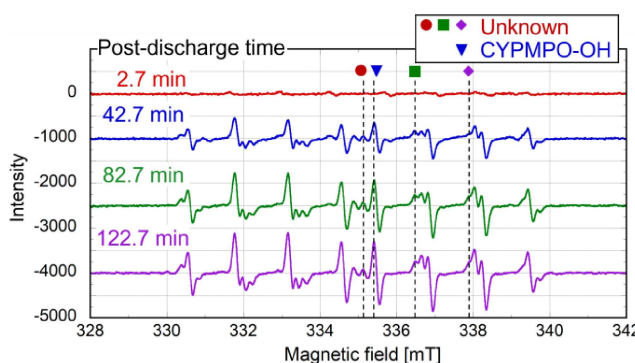


Fig. 1. ESR spectrum of 500 mM sulfuric acid (H₂SO₄) with various post-discharge time when a spin trapping reagent of CYPMPO was added after plasma irradiation.

Plasma Modification of Oxide Catalysts from Starfish

for Efficient Biodiesel Production

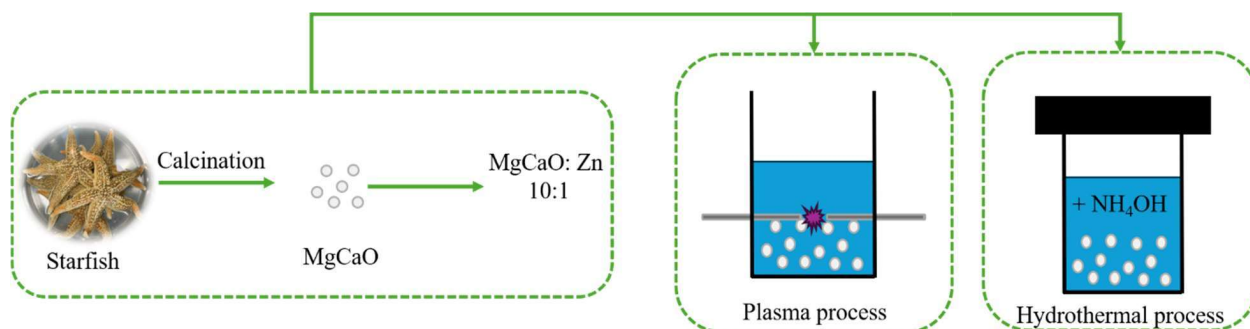
SungHo Lee¹, Jeyoung Ha¹ and Oi Lun Helena Li^{1*}

¹*School of Materials Science and Engineering, Pusan National University*

*E-mail address: helenali@pusan.ac.kr

Keywords: Biomass waste catalyst, Ca-based catalyst, Plasma modification, Biodiesel production

This study used starfish, one of the marine wastes, as a catalyst for biodiesel production through plasma reforming. Since the dried starfish is composed of MgCaCO_3 , heat treatment can easily convert it to MgCaO . These MgO and CaO have been in the spotlight as catalysts for biodiesel, and processes of adding other metals have been studied to improve the stability and performance of the catalysts. In general, such a process is essential for synthesizing catalysts such as ammonia and sodium hydroxide by hydrothermal synthesis and co-precipitation, and these substances may cause problems such as inconvenience in treatment after catalyst production and environmental pollution. In this study, the stability and performance of the catalyst were improved by adding Zn to MgCaO without using materials such as ammonia through the plasma process. Plasma was generated under setting value as 10 kV, 50 kHz, and 1.0 μs using bipolar DC pulse power. The Zn content compared to MgCaO was added at a ratio of 10:1, and it was confirmed through XRD, SEM, and XPS analysis that the catalyst was successfully synthesized. A comparison with the Zn-added catalyst was conducted through hydrothermal synthesis to determine the efficiency of the plasma process. The catalyst's performance was evaluated through the grape seed oil transesterification reaction. Plasma-modified catalysts showed higher yields than hydrothermal synthesis catalysts and maintained performance at 97.7% yields and 93.2% after three reuses.



Ozone Generation by Using Xenon Excimer Lamp and Application for Sterilization on Air Handling Units

Yoshinori Mizuno^{1*}, and Kazuo Shimizu²

¹*Asahi Kogyosha Co. Ltd.*

²*Shizuoka University*

*E-mail address: yoshinori-mizuno@asahikogyosha.co.jp

Keywords: Xenon Excimer Lamp, Ozone, Air Handling Unit

In this study, ozone generation characteristics of xenon excimer lamp has been investigated, and application for Sterilization on air handling units, especially cooling coils or humidifier elements has been discussed. Experimental conditions were 25 °C and 45 % RH.

Xenon excimer lamp was installed in a spiral duct (200 mm diameter). Flow velocity was set at 10 m/s by controlling rotation frequency of fan with checking indicated value of flow meter. Output power of xenon excimer lamp was 14 W, and ozone concentration was maintained at 0.25 ppm. Specific power consumption of ozone generation was calculated as 25 kWh/kg.

For reference, specific power consumption of oxygen discharge is 10 kWh/kg [1]. Although, oxygen discharge type ozone generator requires the expensive auxiliary equipment. This result shows the auxiliary way to generate ozone by xenon excimer lamp which could be utilized for sterilization on small air handling units.

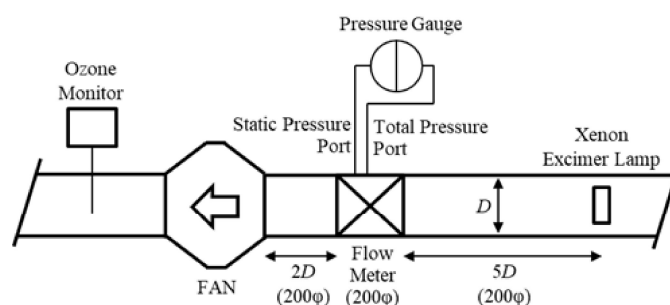


Figure. The schematic image of ozone generation experiment in air duct system.

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Development of Compact Pulsed Power Source and its Applications

Takeshi IHARA*, Satoshi TAKEICHI, Yusuke HIBINO, Takahiko SATAKE,
Yoshihito YAGYU and Hiroharu KAWASAKI

¹National Institute of Technology (KOSEN), Sasebo College

*E-mail address: ihara@sasebo.ac.jp

Keywords: pulsed power, semiconductor, nanosecond, all-solid-state, hydrogen production

Pulsed discharge plasma has been studied in a wide variety of fields such as exhaust gas treatment, ozone generation and sterilization in liquids. Currently, nanosecond pulsed discharges are focused on for high chemical reaction field formation and efficiency. However, nanosecond pulsed power supply is large and expensive. We have developed an all-solid-state compact nanosecond pulsed power supply by driving a SiC-MOSFET. The first type is a pulsed power supply with a high-speed rise time, equipped with an avalanche breakdown transistor for using high voltage pulsed gate signals (Fig. 1). The pulsed power supply generates waveforms with a maximum voltage of 18 kV, a pulse width of 80 ns, and a repetition rate of 1-200 pps. The second one is the pulsed power supply with bipolar output and adjustable pulse width and repetition rate. The pulsed power supply can stably output pulses with a rise time of 20 ns, a maximum output voltage of 1 kV, a pulse half-width of 1 μ s (depending on the load), and a maximum repetition rate of 500 Hz. In addition, experiments of a hydrogen production using water as a raw material were conducted with the first type of pulsed power supply. The experiments confirmed that hydrogen was generated from water using the developed pulsed power supply. Additionally, this presentation introduces the semiconductor human resource development project promoted by KOSEN. Sasebo KOSEN is gaining significant attention for its practical lecture classes conducted in collaboration with industry, government, and academia.

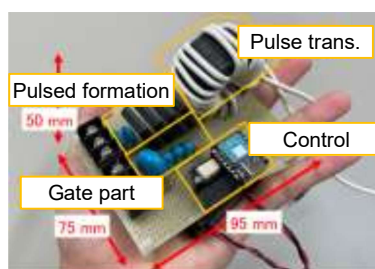


Fig. 1

Energy-efficiency improvement of plasma-induced shock waves

Siwei Liu^{1*}, Yi Liu², Yijia Ren², Tomoki Nakajima¹ and Takehiko Sato¹

¹ Institute of Fluid Science, Tohoku University, 2-1-1, Katahira, Aoba-ku, Sendai, Miyagi, 980-8577, Japan

² School of Electrical and Electronic Engineering, Huazhong University of Science & Technology, Wuhan 430074, Hubei Province, China

*E-mail address: s.liu@tohoku.ac.jp

Keywords: Shock wave, spark discharge, underwater, dielectric property

Shock waves are generally induced by the rapid expansion of the plasma channel against ambient fluid. This research experimentally studies the energy-efficiency improvement of plasma-induced shock waves. The energy deposition was regulated by a novel discharge current interception method [1]. The shapes of the plasma channels and the waveforms of the shock waves can be controlled. The results suggest that only the initial stage of the energy deposition can enhance the shock wave intensity.

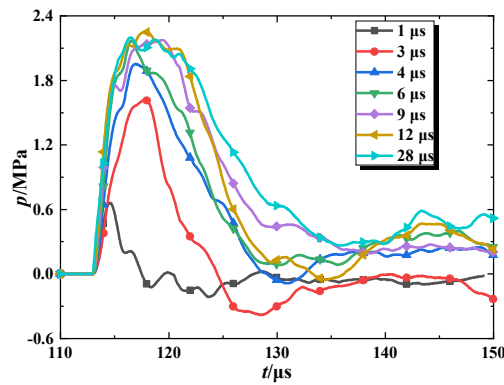


Fig. 1 Waveforms of shock waves with different energy deposition.

Acknowledgments

This study was supported by JSPS KAKENHI (Grant No. 22K14174, 23KK0265).

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Reactions at Plasma-Liquid Interface

Nozomi Takeuchi*

Tokyo Institute of Technology

*E-mail address: takeuchi@ee.e.titech.ac.jp

Keywords: plasma–liquid interface, radical, water treatment, modification of carbon materials

My research group has worked on various applications of plasmas in contact with liquid such as water treatment and modification of carbon materials. Fig. 1 shows physical and chemical phenomena involved in an O₂ plasma process to decompose persistent organic compounds in water using OH radicals [1]. Water evaporation is enhanced by plasma irradiation, resulting in significant generation of OH radicals in the vicinity of the plasma–liquid interface. We did a numerical simulation to investigate how OH radicals are generated and lost, penetrate into a solution, and react with organic compounds [2]. Then, we proposed plasma–ozone combination processes to maximize the energy efficiency [1]. Recent years, plasmas in contact with liquid became key technologies for the decomposition of perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA). Energetic species such as electron, ions, and neutrals can efficiently collide with the molecules of PFOS and PFOA owing to their surfactant characteristics, which enables very efficient decomposition of these molecules to CO₂ and fluoride ions [3],[4].

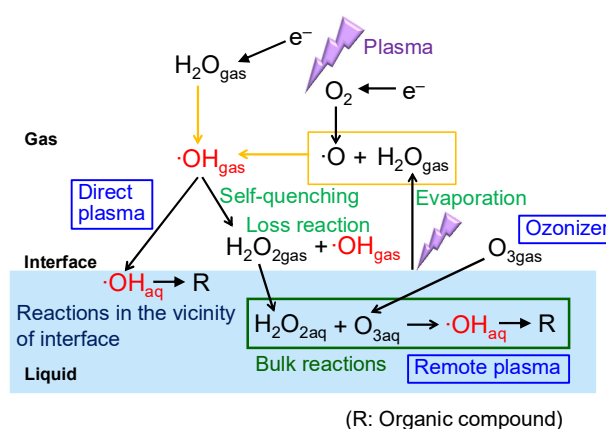


Fig. 1. Important phenomena in the decomposition of organic compounds using O₂ plasma [1].

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Plasma-Enhanced Germination: A Novel Approach to Boost Plant Growth

Siraporn Chuea-uan ^{1*}, Dheerawan Boonyawan ², Choncharoen Sawangrat ³, Chanchai Dechthummarong ⁴,
Natchaya Saikamwong ¹, Nattaya Hompian ¹, and Sa-nguansak Thanapornpoonpong ¹

¹ Department of Plant and Soil Sciences, Faculty of Agriculture, Chiang Mai University, Chiang Mai 50200, Thailand

² Department of Physics and Materials Science, Faculty of Science, Chiang Mai University, Chiang Mai 50200, Thailand

³ Department of Industrial Engineering, Faculty of Engineering, Chiang Mai University, Chiang Mai 50200, Thailand

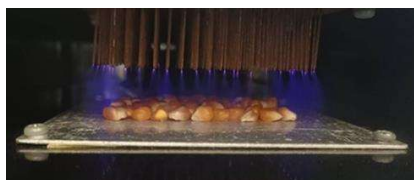
⁴ Department of Electrical Engineering, Faculty of Engineering, Rajamangala University of Technology Lanna,
Chiang Mai 50300, Thailand

* siraporn_chueauan@cmu.ac.th, siraporn.ripon@gmail.com

Plasma technology is becoming a highly effective approach to improve seed quality and promote plant growth, marking a promising advancement in agriculture. The use of low-temperature atmospheric pressure plasma utilizes reactive oxygen and nitrogen species (RONS), which are introduced into the physiological components of seed through various mechanisms to promote germination and growth.

The research investigates the effects of air plasma and plasma-activated water (PAW) treatments on seed quality, focusing on the optimal conditions for each technique. For maize seeds, it was found that using air corona plasma at a voltage of 150 volts for 75 seconds significantly enhanced germination quality. Similarly, applying air surface dielectric barrier discharge plasma to maize seeds for 60 seconds was found to be the most suitable for increasing germination, growth parameters, and reducing pathogens on the seed surface. Additionally, using air gliding arc plasma to generate PAW for rice seed treatment significantly increased germination, early growth stages, and total nitrogen content in rice seedlings.

Plasma treatment effectively enhances seed quality and stimulates plant growth by introducing RONS. Research indicates that air plasma and PAW treatments significantly enhance germination and boost early growth in maize and rice seeds, providing an eco-friendly alternative to traditional methods.



Corona



Surface Dielectric Barrier Discharge



Gliding Arc

Keywords: plasma, corona, surface dielectric barrier discharge, gliding arc, germination, plant growth

Environmental and Agricultural Applications of Atmospheric Pulsed Discharges Generated by Compact Pulsed Power Generators

Katsuyuki Takahashi^{1*}, and Koichi Takaki

¹ Faculty of Science and Engineering, Iwate University, Morioka, Iwate, Japan

² Agri-Innovation Center, Iwate University, Morioka Iwate, Japan

*E-mail address: ktaka@iwate-u.ac.jp

Keywords: (High voltage, pulsed power, streamer discharge, radical, agriculture)

The use of pulsed electric field and non-thermal plasmas generated by pulsed power generators has been widely developed. Our research group has developed a compact generator using a novel 13 kV SiC-MOSFET molded into a compact modified TO-268 package for use anywhere and by anyone (figure 1). For environmental applications, gas treatment such as decomposition of toxic and odour components and aerosol removal using streamer discharges (figure 2), and water treatment using discharges generated over the water surface have been studied. The study of agricultural applications has been carried out for three purposes; to improve productivity of plants in pre-harvest applications, to maintain the freshness of fruit and vegetables in post-harvest applications, and to improve safety and productivity in food processing applications. In this presentation, some applications and details of the specification of pulsed power systems will be presented.

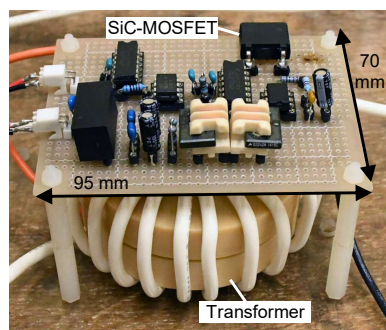


Fig. 1 IES pulsed power generator

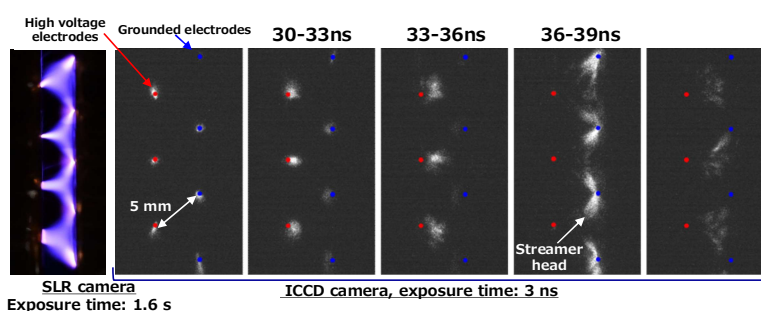


Fig. 2 Photographs of streamer discharges