Institute of Fluid Science
Tohoku University
Biological Nanoscale Reactive Flow Laboratory

TOHOKU UNIVERSITY

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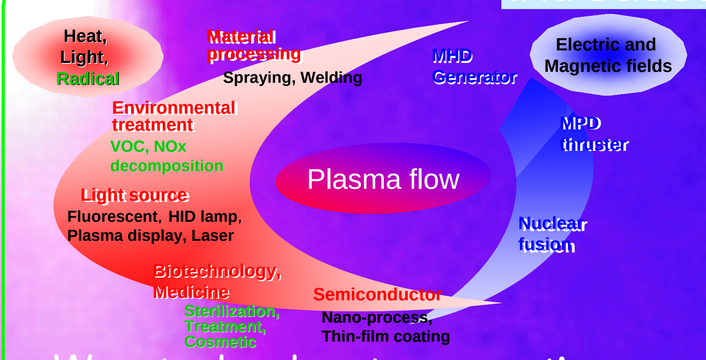
As a low-temperature plasma flow at atmospheric pressure is easily capable of generating heat, light, chemical species, charged particles, shock wave, etc., recently, a research on a sterilization and a plasma treatment has started using those physical features. The biological nanoscale reactive flow laboratory aims at a fundamental study and applications of "plasma medicine", which is expected to become a next-generation medical technology, through the studies on activation and inactivation processes of cells, development of a plasma sterilization method, phenomena of reactive flow dynamics and nanoscale flow dynamics for a gas-liquid plasma and interactions between a plasma flow and cell/bacteria.

Introduction



Plasma has been applied to a wide range of fields, and it is necessary to approach from different points of view, e.g., electric, chemical, material, and thermal fluid fields.

We study about generation and transportation mechanisms of radicals by plasma flow at atmospheric pressure generated in gas-liquid flow, interaction mechanisms between plasma and biological objects, bubble generation and collapse processes by gas-liquid plasma flow, and numerical analyses of reaction processes. Also, we promote the basic research for the practical use, through joint researches with universities, research institutes, and companies all over the world.

JSME Fluids Engineering Division News Letter "Plasma flow at atmospheric pressure", December 2007.
http://www.jsme-fed.org/newsletters/index.html

Sterilization device and mechanism by low-temperature plasma at atmospheric pressure

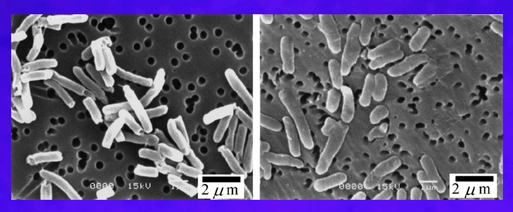
OMicrowave argon plasma flow

To reduce infection risks of new influenza, nosocomial infection and so on, and to develop next-generation medical instruments, we aim at clarifying generation and transportation mechanisms of a plasma flow by experimental and computational analyses and we also aim at identifying the central factor of sterilization effect and clarifying sterilization mechanism.


Photograph


N_2*

Visualization

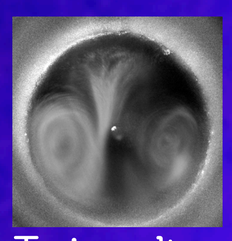


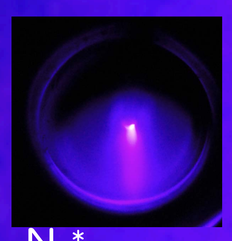
Effect of plasma flow on *E. coli*. Treated (R)

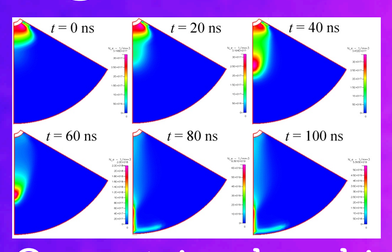
T. Sato et al., Applied Physics Letters, 89 (2006), 073902.
T. Sato et al., IEEE Trans. Industry Appli., 42 (2006), 399.
T. Sato et al., IEEE Trans. Industry Appli., 43 (2007), 1159.
T. Miyahara et. al, Europhysics Letters, 86 (2009), 45001.
T. Sato et al., New Journal of Physics, 11 (2009), 115018.
PCT/JP2005/15431, 特願2007-001999, Patent 2008-06604

OSterilization in a tube

Application to medical equipments such as catheter sterilization by radical generation, transport and concentration using plasma flow control. For example, optimum sterilization conditions are 5 min, 70 ℃ and 13 W for a tube of 100 mm length and 3 mm i.d.


Twin voltex


N_2* emission

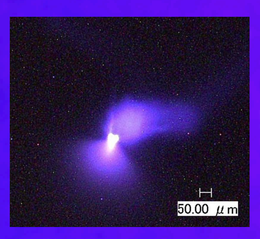


Computaional analyis of streamer propagation

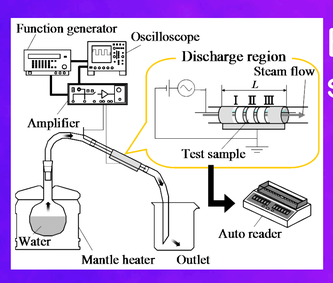
T. Sato et al., Plasma Processes and Polymers, 5 (2008), 606.
T. Sato et al.., IEEE Trans. Industry Appli., 45 (2009) , 44.
Patent JP4898635, JP4902842
PCT/JP2006/315958, etc.

OPlasma autoclave

Development of steam sterilization system for medical equipments at 100℃ and atmospheric pressure by controlling OH radical generation and transport. We succeeded in sterilizing bacteria spores within 30 min.



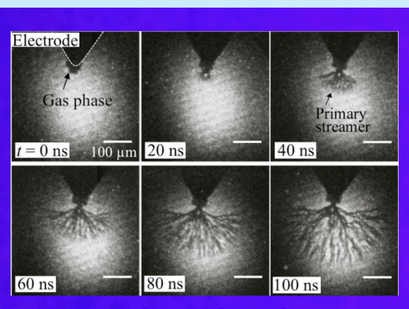
Steam plasma flow



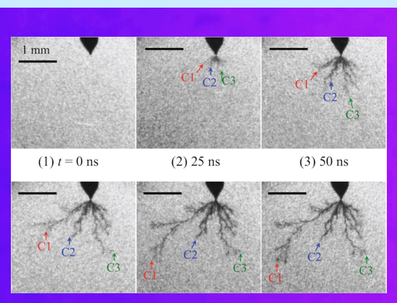
Experimental setup

T. Furui, T. Sato, JSME Journal B, 70 (2008), 879. [in Japanese]

Initiation and propagation mechanism of underwater streamers



Propagation of underwater primary stremer



Propagation of underwater secondary streamer

We clarified that a primary streamer propagated intermittently synchronized with appearance of pulsed currents and a secondary streamer propagated with around 20 km/s during a continuous current appears.

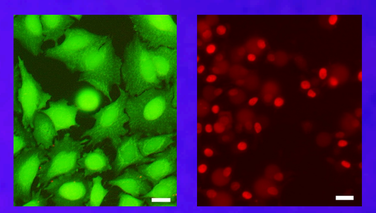
H. Fujita et al., J. Appl. Phys. 113 (2013), 113304.
H. Fujita et al., EPL, 105 (2014), 15003.
H. Fujita et al., J. Appl. Phys. 116 (2014), 213301.

Joint researches: Max-Planck-Institute for Extraterrestrial Physics(Germany), Ecole Polytechnique Federale de Lausanne (Switzerland), Shizuoka University, Shinshu University, Tohoku University, Oita University, etc.

Activation and inactivation processes of cell viability by atmospheric pressure plasma flow

We aim at clarifying the effects on cells by chemical species generated by plasma, and aim for the fundamental study and the application.

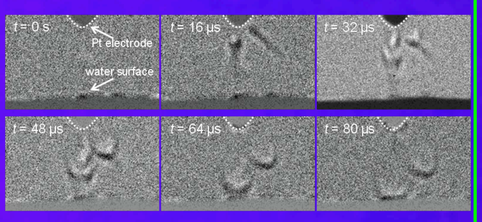
We have now studied about the activation and inactivation mechanism of cell viability by a plasma flow, and the transport mechanism of chemical species generated by the plasma flow.


Fluorescence image of HeLa cells. Regular (Left). Cell death after exposure (Right).

T. Sato et al., J. Phys. D: Appl. Phys., 44 (2011), 372001
M. Yokoyama et al., BBRC, 450 (2014), 1266
T. Miyahara et al., AIP Advances, 4 (2014), 047115

Chemical transport by plasma actuator

To apply medical applications and environmental treatment, we have clarified flow patterns and mechanisms of plasma induced flow. Bullet type of thermal flow is generated when plasma is generated from the tip of electrode to the water surface. This flow generates circulating flow in water and enhances the chemical transport generated by plasma.



High speed images of plasma induced flow in the plasma-water system.

T. Shimizu et al., New J. Phys., 13 (2011), 053025.
T. Shimizu et al., J. Photochem. Sci. Tech., 24 (2011), 421R.

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