【Grant-in-Aid for Scientific Research (S)】

Overall Understanding of Diverse Multidimensional Distributions in Plasma Processes for Functional Outputs

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Purpose and Background of the Research

●Outline of the Research

Plasma (*1), which is observed as a thunder in nature, is popular in many industrial activities, varying its outlook. However, our in-situ control for plasma processes in industry is incomplete because we are forced to handle it without accurate knowledge of variable distributions. Even if accurate monitoring of the internal parameters was possible, cause-effect connections would be too complex to manipulate them; for instance, a chemical system in molecular plasma includes hundreds of reactions. In this study, not identifying each microscopic element, we grasp macroscopic trends over statistics in distributions. Collective properties of elements distributed in plasma are useful for this purpose, in particular, such as entropy (*2) as a quantity and scalefreeness (*3) in qualities. Then, we can diagnose a system state with its stability and whereabouts by experimental data in test reactors and theoretical analyses in computer calculations. These results will give us a reason why each working state selected in industrial plasma can be reproduced every operational run and also lead to an advanced design for process recipes which achieve higher functionalities.

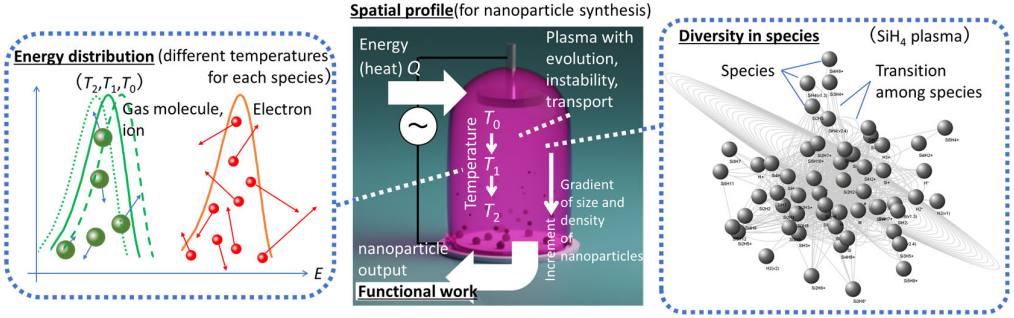

Figure 1. Conceptual view of this study on spatial/energy distributions and species diversity in plasma.

●What is plasma, and what do entropy and scalefreeness unveil?

(*1) *Plasma*: a state composed of electrons and ions with radical species and light emissions. Plasma in industry is regulated by external knobs, inevitable for many products.

(*2) *Entropy*: defined as heat Q transferred to the system divided by temperature T. It is also well-known in the Second Law of thermodynamics saying that entropy always increases in spontaneous processes, and also implies a level of uncertainty level in the system.

(*3) *Scalefreeness*: a well-observed property in large-size network that consists of numerous nodes and links. More linkages a node has, less its count is in scalefree network, and this is a measure of network robustness.

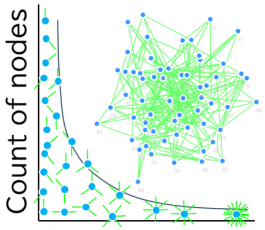

Figure 2. Network and its scalefreeness.

●Functions and outputs that plasma can offer

Plasma plays essential roles in fabrication of semiconductor devices. In this study, we study nano-particle formation for rechargeable batteries, analog computing for navigation system in logistics, and chemical inter-connection between plasma and biological cells as well, which possess potentials for near-future industries.

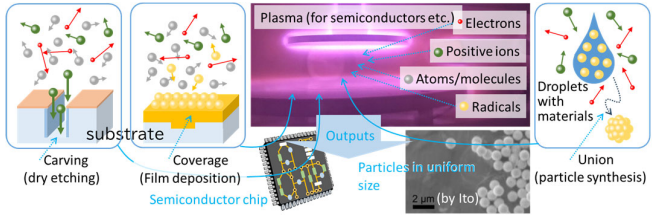

Figure 3. Plasma in industries: outlook, functions, and outputs.

Expected Research Achievements

●Plasmas we will study with their distributions, and resultant outputs

Group of six researchers examine plasma experimentally and theoretically for keys.

○Three different energy distributions for nano-particle synthesis (main members: Tsuyohito Ito (Univ. Tokyo), Manabu Tanaka (Kyushu Univ.), Makoto Kambara (Osaka Univ.)))
How are effects coming from different energy distributions?

○Strange forms of plasmas: novel-output tools (main members: Osamu Sakai, Satoshi Hirayama (Univ. Shiga Pref.))
Why do such configurations exist? For logistic navigation?

○Synthesis of plasma and biological chemical systems (main members: Tomoyuki Murakami (Seikei Univ.), Osamu Sakai)
What happens when two complex systems meet?

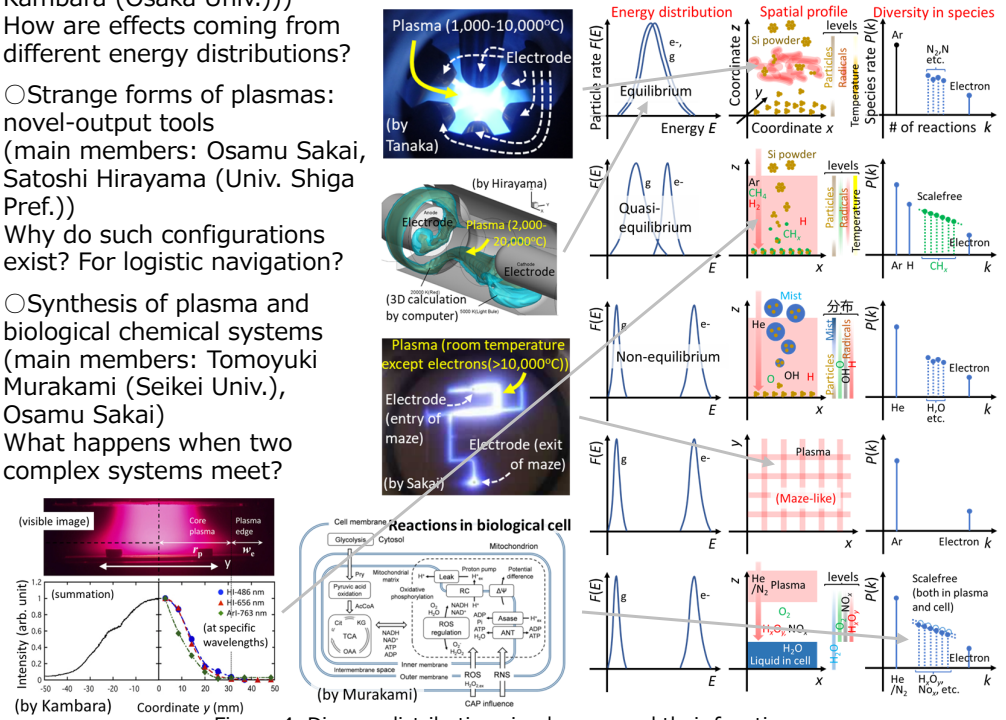

Figure 4. Diverse distributions in plasmas and their functions.

●Our goals (new science and near-future industrial activities)

We aim at establishing science for handling and optimizing complex phenomena, by introducing entropy and scalefreeness into areas that have not experienced them. For future society, we demonstrate *new tech tools with diverse functions with various distributions*, leading to *newly-conceptual next-generation factories*.

Homepage Address, etc.	Regional ICT research center for human, industry and future at The University of Shiga Prefecture offers information in the following web page and hosts symposiums/workshops: https://www.ict.usp.ac.jp/