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低温大気圧プラズマによる細胞死制御のモデリング
Modelling of the cell death control with cold atmospheric plasmas

村上 朝之
Tomoyuki MURAKAMI

成蹊大学
Seikei University

Cold atmospheric plasmas (CAPs) have been widely applied in the field of biomedicine, whereas mathematical models suitable for understanding the CAP-induced biological effects are necessary. Recently, to clarify the effects of plasma-derived species on the intracellular functions, a biochemical network of mitochondrial redox homeostasis and energy metabolism has been modelled [1].

The present work proposes an integrated scheme of a gas-phase plasma model, a liquid chemistry model and an intracellular model to examine the CAP-induced cell survival/death phenomena.

Figure 1 shows a conceptual illustration of the proposed model. A DBD-discharge plasma source is operated in a room-temperature atmospheric environment. A biological target covered with air-saturated liquid is placed beside the CAP device. This work focuses on chemical species such as reactive oxygen/nitrogen species (RONS) which are generated and applied to biological targets and can affect the living body. Through the numerical work, it is possible to predict the trajectory of RONS from the source to the target while obtaining an overview of the more general framework of the plasma-biology interactions.

Modelling the gas-phase phenomena. A one-dimensional (r-direction) simulation (drift-diffusion model coupled with humid air reaction set) [2] is performed to clarify the RONS concentration in the core region (between the electrode and dielectric) of the CAP device. In addition, a two-dimensional (r-z direction) turbulent simulation is performed to reveal the afterglow behaviour. The gas components fed to the CAP device are changed under a wide range of air mixing conditions, from nitrogen plasma to humid air plasma. The RONS activated in the core region are released into environment. The passive chemistry caused by the interaction between the RONS and ambient air components affects the afterglow. Then, some of them reach the target.

Modelling the liquid-phase chemistry. A one-dimensional (z- (depth-) direction) model simulates the saturated atmospheric water chemistry. The RONS at the liquid surface which is estimated from the afterglow simulation influences the aqueous chemistry.

Modelling the intracellular functions. A zero-dimensional numerical simulation is used to describe the intracellular biochemical reaction in which a variety of pro-/anti-apoptosis agents are involved. Based on the RONS distribution obtained in the liquid phase reaction model, the mechanism of cell death induction by external chemical stimuli was examined.

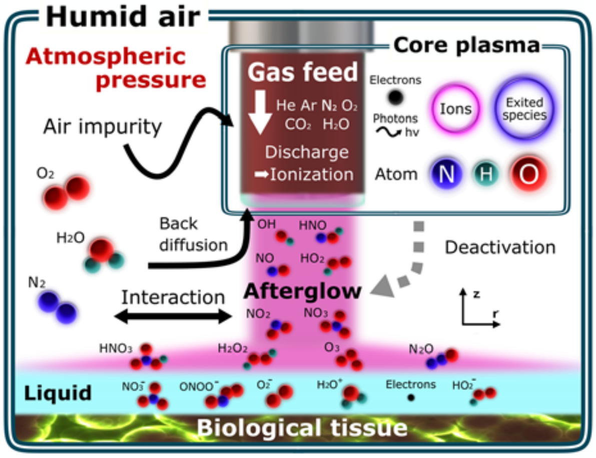

Fig.1: Conceptual illustration of the proposed model.

References
[1] T. Murakami, Sci. Rep. **9**, 17138 (2019).
[2] T. Murakami and O. Sakai, Plasma Sources Sci. Technol. **29**, 115018 (2020).