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Visualization of Two-Dimensional Colorimetric Reactions of Reactive Oxygen Species Using KI-Starch Reagent

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Atmospheric pressure plasma irradiation has attracted considerable attention in recent years for its ability to induce oxidation reactions and generate reactive chemical species, with applications spanning material surface modification and agriculture [1–4]. To optimize these applications, it is critical to elucidate the dynamics of reactive oxygen species (ROS) generated during plasma exposure. Previous studies have successfully visualized the two-dimensional distribution of ROS through plasma jet irradiation onto KI-starch reagents [5]. However, it has generally been understood that the KI-starch react with any molecule possessing an oxidation potential greater than 0.54 V, limiting the method's ability to distinguish among different ROS species.

In this experiment, we studied the spatiotemporal dynamics of the coloring of KI starch depending on the specific molecule of the ROS to create a simple measurement method of ROSs. By selectively generating O, OH, and H_2O_2 using vacuum ultraviolet (VUV) irradiation, we analyzed the resulting spatiotemporal distribution of color reaction.

A KI-starch gel reagent was employed to visualize the two-dimensional distribution of ROS. When typical ROS, such as hydrogen peroxide, reacts with the initially colorless gel, producing a purple coloration. Material gas molecules were introduced into a quartz tube and decomposed via VUV irradiation, enabling selective ROS generation [11]. During the experiment, the distance between the quartz tube outlet and the KI-starch gel surface was set at 1 mm. Following VUV irradiation for 1 minute, and after a standing period of 15 minutes, the gels were scanned,
and the resulting images were analyzed using ImageJ software to obtain optical density (OD) values.

Figure 1 presents the coloration of the KI-starch reagent after 450 seconds of irradiation with 1.72 ppm hydrogen peroxide. Comparison between 1 minute after irradiation and 15 minutes after irradiation reveals that both the intensity and the spread of the colored region increased over time. To quantitatively assess the coloration, OD values were measured along a line from point A to point B. The maximum OD values were 0.1 at 1 minute and 0.25 at 15 minutes, indicating that ROS continued to react with the reagent even after irradiation ceased, leading to an increase in both OD value and coloration area over time.

This study researched the generation and reaction characteristics of ROS induced by VUV irradiation using KI-starch method. Future work will focus on the precise identification and quantitative analysis of individual ROS species.

References

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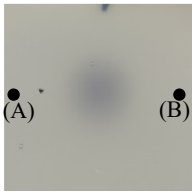
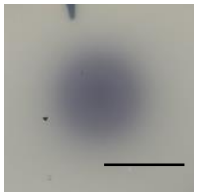


1 min after irradiation


15 min after irradiation

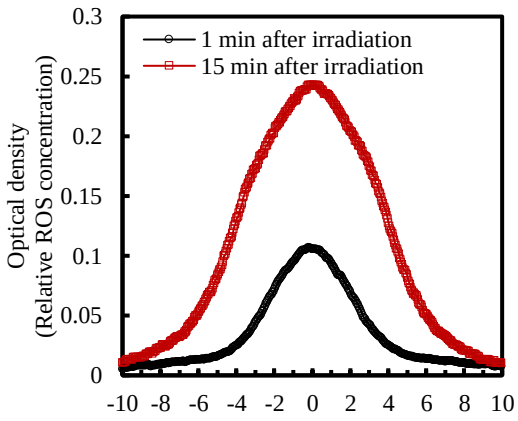


Figure 1. Color reaction on KI-starch gel after H_2O_2 irradiation for 1 min after irradiation and 15 min after irradiation. Scale bar shows 5 mm. Relative ROS concentration profiles 1 min and 15 min after irradiation obtained by optical density analysis along the AB lines.