Tracing plasma-produced reactive species in a skin-mimetic environment for skin plasma patch treatment

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Abstract: In this study, we analyzed the gaseous reactive species generated by the plasma patch designed to be attachable to the skin and investigated how these species dissolve in skin mimetic liquid materials. O_3 and N_2O_5 were generated by the plasma patch and dissolved in water, forming H_2O_2, NO_2^- and NO_3^-.

1. Introduction

Polymer-based flexible materials such as polyimide (PI) have recently begun to be used as dielectric materials in medical plasma patches. Since its flexibility and adhesion to skin, it has advantage that it can properly transmit plasma-produced reactive species effect to skin. One of the characteristics of the plasma patch is that the dielectric barrier is too thin to increase power transiting to NOx mode, it is well known that ROS (reactive oxygen species) absorbed through the skin help for disease such as psoriasis [1]. However, since RNS (reactive nitrogen species) is also well known as very helpful in improving skin diseases, it was necessary to track RNS occurrence even if the plasma patch was operated in O_3 mode.

Therefore, in this study, we prepared a liquid material that can mimicking the condition of skin, and identified the chemical pathways by which ROS and RNS generation at gaseous and aqueous phase simultaneously depending on plasma driving conditions, and elucidated the mechanism.

2. Methods

Plasma patch was consisted of screen-printed silver electrodes and a sheet of PI film. Plasma patch was placed at the top of the chamber, allowing reactive species to diffuse downwards. To simulate skin attachment, liquid materials placed bottom of the chamber, and the diffusion layer was minimized maintaining only the space for optical absorption spectroscopy measurement [2]. Additionally, COMSOL based 0-D computational simulations were conducted to figure out the process of RONS generation, diffusion and dissolution.

3. Results and Discussion

Plasma patch-liquid material interaction experiment were illustrated in Fig 1. Fig. 1 (a) shows that touching the plasma patch in operation does not cause any electric damage to skin. Fig. 1 (b) and (c) demonstrates that the identified gaseous species were primarily N_2O_5 as well as O_3, these are become H_2O_2, NO_2^-, and NO_3^- in aqueous phase. N_2O_5 becomes main sources of NO_2^- and NO_3^- in liquid material via following reaction: $N_2O_5 + H_2O \rightarrow 2H^+ + 2NO_3^-$ [3]. H_2O_2 and NO_2^- were expected to be produced by another chemical reactions rather than N_2O_5 dissolution.

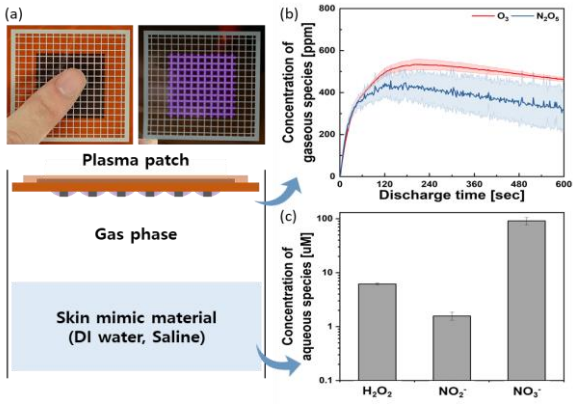

Fig. 1. (a) Schematic of the plasma patch-liquid material model and images of plasma patch during discharge. (b) Concentration of reactive species generated from plasma patch and (c) dissolved in water.

After discharge, NO_3^- maintain its concentration while NO_2^- increase since ionization of HNO_2. These reactions were verified by 0-D numerical simulations.

4. Conclusion

Even when the plasma patch is operated in O_3 mode, about tens of ppm of N_2O_5 were measured in the gaseous phase, proving that it is a source of NO_2^- and NO_3^- in the aqueous phase. This was confirmed by in-situ measurements and 0-D numerical calculations. This result provides very valuable information that the influence of RNS should not be ignored even in skin application using the plasma patch.

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References

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