Optical observation of He_2^* excimers in He/N_2 cryoplasma

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[Background] Our group has developed a novel plasma source called croyplasma, where the gas temperature can be controlled continuously between 273-5 K [1]. The development of cryoplasma potentially extends the current industrial applications of non-equilbrium low temperature plasma to cryogenic temperatures, with promising applications in materials processing in bio-medical and semiconductor industry.

In cryoplasma, plasma chemistry varies with plasma gas temperature. For example, in helium (He) cryoplasma, metastable helium atoms have long lifetimes at cryogenic gas temperatures, and helium excimer (He_2^*) emission ($d^3\Sigma_u^+ \rightarrow b^3\Sigma_g^+, 640$ nm) was observed at gas temperatures below 45 K [2]. In this study, in order to gain a better understanding of the plasma chemistry in He/N_2 system, a multiple gas cryoplasma, both solid phase and gaseous N_2 were introduced into the discharge. Optical emission spectroscopy in the visible and near ultraviolet range has been performed.

[Methods] The plasma source used in this study was a cryogenic dielectric barrier discharge (DBD), with polyimide film as the dielectric layer. The plasma reactor was first filled with He and 0.2% N_2 gas at room temperature. Next, the reactor was cooled to 45 K, such that both solid and gaseous N_2 were present in the reactor. At pressure 2×10^3 Pa, 0.8 kV_{pp} sinusoidal AC voltage was applied at 10 kHz to the top electrode to generate DBD. Plasma characteristics were measured by optical emission spectroscopy using a spectrophotometer.

[Results and discussion] The optical emission spectrum from the cryoplasma is shown in Figure 1. Molecular transition features were observed, which we have assigned to the emissions from He_2^* excimer. In addition to the emission of He_2^* excimers at 640 nm which has been previously reported in helium cryoplasma without introduction of N_2 gas [2], in this study, with introduction of a small amount of N_2, other emissions of He_2^* excimers from highly lying energy states (close to 21 eV [3]) were observed between 520-600 nm. These transitions had only been observed in liquid He [3, 4] and we believe it is the first observation from cryoplasma under He/N_2 gas mixture. While further investigations will be followed to identify the origin of these transitions, one possible explanation is an important contribution of energy transfer between He_2^* excimers and N_2. We are confident that the mechanism for the formation of He_2^* excimers in cryoplasma will provide an efficient excitation pathway to tailor the production of transient species.

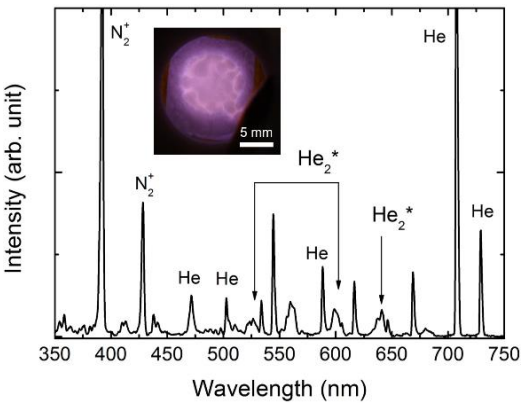

Figure 1. Optical emission spectrum at 45 K. Inset: Photograph of He/N_2 cryoplasma.

References

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