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Development of Nitrogen Vibrational Excitation Plasma Source with Repetitive Nanosecond Pulses

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Recently, nitrogen fixation using plasma, which is a way to synthesis nitrogen compounds, is gaining interest, due to the necessity of nitrogen for producing fertilizers [1]. For efficient nitrogen fixation, the contribution of the vibrationally excited nitrogen reaction with the atomic oxygen (Zeldovich mechanism) is the key in the plasma nitrogen fixation. Furthermore, atmospheric pressure plasma source for the vibrational excitation might be preferred to have rapid response to vary its power consumption to unstable power sources such as the green power sources. We developed a Non-Self-Sustaining (NSS) DC discharge plasma source [2] that allows us to vibrationally excite the nitrogen and investigated its discharge characteristics.

For efficient vibrational excitation of nitrogen molecule, approximately 1 Td to 50 Td of reduced electric field is known to be efficient [3], but is lower than the self-sustaining discharge voltage (~10^2 Td). The developed NSS DC discharge plasma source (Figure 1) is powered by both a nanosecond high voltage pulse generator for ionization and a DC power supply for the major power loading to the nitrogen molecules with controlled DC voltage (V_{DC}). With the applied DC voltage, the amplitude of the reduced electric field can be controlled. In this study, the apparent reduced electric field of 1 Td has been studied under 0.2 atm nitrogen (P_{N2}). The repetition rate of the nanosecond pulses f_{pulse} is varied up to 35 kHz. A single pulse burst discharge is operated at a certain repetition rate and consisted of 200 nanosecond pulses (n_{pulse}).

Figure 2 shows the electrical current through the electrode gap during the discharge with V_{DC} = 360 V. The pulse burst begins at 0 μs and ends at 13.3, 10.0, 8.89, 8.00, 6.67, and 5.71 ms, depending on f_{pulse} of 15.0, 20.0, 22.5, 25.0, 30.0, and 35.0 kHz, respectively. It is important to note that every nanosecond pulse generates the pulse discharge but the pulse current waveform is intentionally filtered off with lowpass and median filters to show the NSS DC discharge current in Fig.2. It is found that the NSS DC discharge is generated during the burst when the frequency higher than 20 kHz with the given discharge electrode configuration in Fig.1. Figure 3 shows the electrical current at 150th pulse. When the frequency is below 30 kHz, the current starts to flow through the electrode gap at approximately 2 μs and then the current, caused by the pulse, decreases to zero with time. Because the DC voltage is kept at 360 V regardless of the pulses, this intermittent current through the electrodes indicates the NSS DC discharge characteristic. Also, Figures 2 and 3 show that similar current waveform between the pulse but the pulse interval is varied by f_{pulse}. Therefore, the mean electrical current and the coupling power can be controlled with f_{pulse} without changing the applied DC voltage. At f_{pulse} = 35 kHz, the current does not completely decrease to zero, and it is held until the next pulse. This continuous DC discharge current is gradually built up during the burst but shut off at the end of the burst as shown in Fig.2. This continuous DC current results in the mean electrical current higher than 1 A, and thus higher power loading is achieved. However, this leads to a voltage drop between the electrodes due to the circuit resistance, meaning that the reduced electric field is expected lower than those at the lower f_{pulse}.

In conclusion, we have developed NSS DC discharge plasma source, and demonstrated the NSS DC discharge characteristic. Further results will be discussed in the meeting.

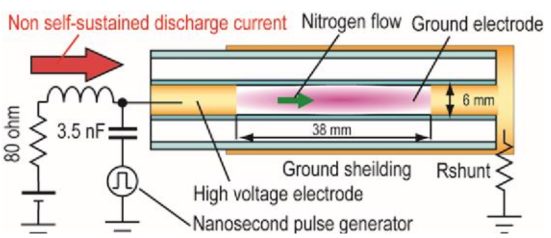

Figure 1. Non-Self-Sustaining DC discharge plasma source.

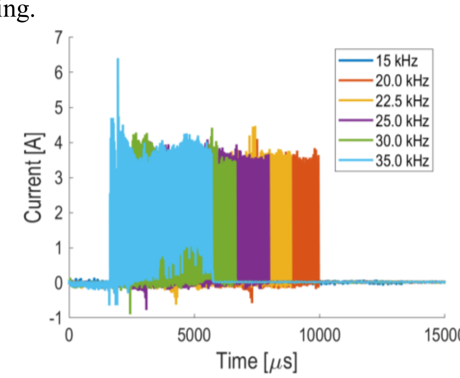

Figure 2. Current between the electrodes. V_{DC} = 360 V, f_{pulse} = 15 ~ 35 kHz, n_{pulse} = 200, P_{N2} = 0.2 atm.

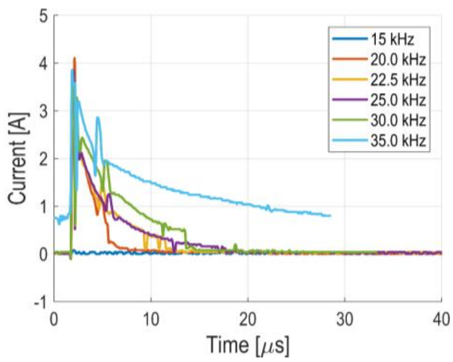

Figure 3. Current between the electrodes at 150th pulse.

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