# Simulation Study of High-Frequency Pulsed DC Discharges in Nitrogen

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**Introduction**: In this paper, a two-dimensional finite element model is used to investigate the high frequency pulsed DC discharges in nitrogen. The study is performed using the Plasma Module of COMSOL Multiphysics@. The densities of all the plasma species are obtained. The temporal evolutions of averaged electron density, averaged electron temperature, and averaged densities of ions and neutrals are presented. The effects of pulse frequencies and duty cycle ratios on plasma properties are examined.

**Computational Model**: The research is conducted in a DC glow discharge device designed for metal nitridation. Gas is nitrogen. The gas pressure is 10 Pa. A negative high voltage of –2 kV at the pulse repetition frequency of 1 or 10 kHz is connected to the cathode through a series RC circuit comprised of a ballast resistor of 100 Ω and a blocking capacitor of 50 nF. The duty cycle ratios (discharge ON time/discharge pulse period, DCR) are 25% and 50%. The species taken into account are electrons, ions ($N_2^+$, $N_4^+$, $N^+$), neutrals in ground state ($N_2$, N), and neutrals in excited state ($N_2(A^3\Sigma_u^+)$, $N_2(B^3\Pi_g)$, $N_2(B'\ ^3\Sigma_u^-)$, $N_2(a'\ ^1\Sigma_u^-)$, $N_2(a\ ^1\Pi_g)$, $N_2(w\ ^1\Delta_u)$, $N_2(C\ ^3\Pi_u)$). 34 kinds of chemical reactions, in which the electron-induced collisions, the reactions of ions by collisions with atoms and molecules, the reactions of excited nitrogen molecules by collisions with atoms and molecules, and the photoemissions are included. The secondary electron emission coefficient is set to 0.25.

**Results**: Calculations are performed for 20 cycles of the pulsed DC and the calculated results for the latter half (10 cycles) are shown in Figs.1 and 2. The number of mesh elements is 11527. The typical computational time for the pulse frequency of 1 kHz and 25% DCR is 90 hours and 58 minutes .

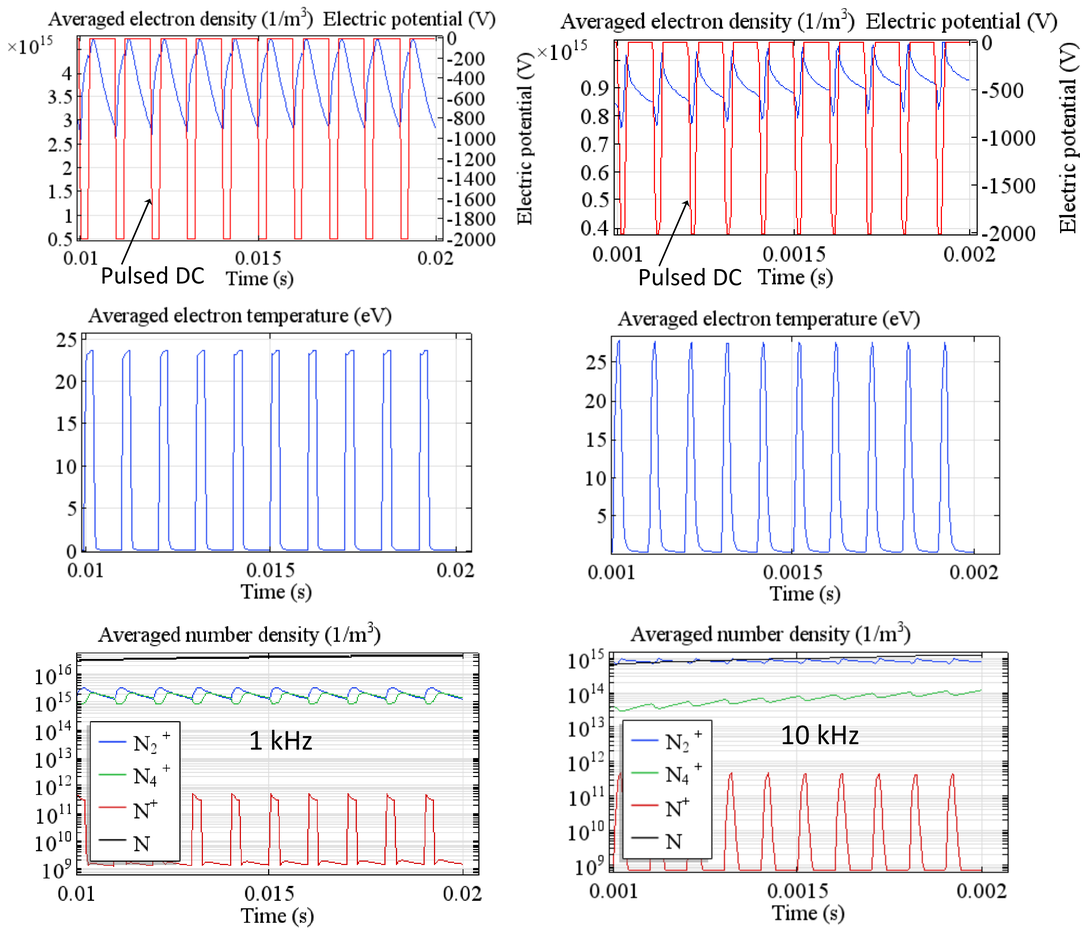


**Figure 1**. Temporal evolutions of averaged electron density, averaged electron temperature, and averaged densities of ions and neutrals in a pulsed DC plasma with 25% DCR.

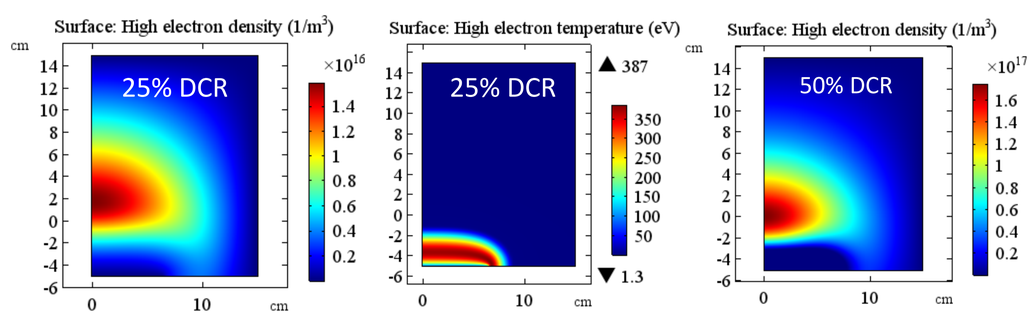


**Figure 2**. High electron density and high electron temperature in a pulsed DC plasma at 1 kHz .

**Conclusions**: This paper presents the simulation results of the high frequency pulsed DC discharges in nitrogen. The pulsed plasma properties are obtained. The extremely high electron temperature is shown over the cathode at the maximum amplitude of pulsed DC voltage. The increase of DCR causes the electron density to rise rapidly. Contrarily, an increase of the pulse frequency causes the electron density to go down. .

**References**:

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