Formation and annihilation of O_2^--ions in an oxygen discharge

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Depending on the pressure and power, the density of O_2^--ions can be close to the density of O^--ions and it can become an important species for the charge neutrality in the plasma. Here we study the main channels for formation and annihilation of O_2^--ions through a Volume Averaged Global Model in the pressure range from 0.5 – 100 mTorr. Results show that formation of O_2^- is a charge exchange dominated process; however, many reactions contribute to the loss of O_2^- and their contributions change in the range of pressure studied. For pressures below 2 mTorr, in a stainless steel cylindrical chamber, the loss of O_2^--ions is dominated by mutual neutralization of O_2^- and O_2^+. For an anodized aluminium chamber loss of O_2^--ions is dominated by detachment reactions between O_2^- and $O(^3P)$. The results also show the importance of the metastable states for the oxygen discharge.

Volume Averaged Global Model studies of inductively coupled oxygen discharges have shown that the mean density of O_2^--ions increases as pressure increases reaching values close to the mean density of O^--ions in the 100 mTorr range [1, 2]. Calculations were carried out for a stainless steel and anodized aluminium cylindrical reactor chamber with radius R = 15 cm and length L = 30 cm. The flow rate of oxygen feedstock is 50 sccm, the gas temperature is 600 K, and the absorbed power is 500 W. It was found that formation of O_2^- occurs mostly through charge exchange between O^- and $O_2(X^3\Sigma_g^-)$, $O^- + O_2(X^3\Sigma_g^-) \rightarrow O(^3P) + O_2^-$, in both stainless steel and anodized aluminium chambers. This channel remains the main channel for the formation of O_2^--ions even when changes in the electron energy distribution function are considered.

Figure 1 shows the reaction rates for the main reactions which have significant contributions to the O_2^- loss process. These reactions are shown in Table 1. The full reaction set used in the model can be found elsewhere [1]. Note that, for pressures below 2 mTorr, in a stainless steel chamber, reactions 5 and 6 are the dominant channels. In an anodized aluminium chamber, detachment reactions between O_2^- and $O(^3P)$ are the main channels for the O_2^- loss process. As the pressure increases, the reaction rates for reactions 1, 2, 3, and 4 increases. Thus, the loss process for O_2^- is not dominated by only one reaction, but many reactions contribute to it and the role of each reaction is heavily pressure dependent. These results also show the importance of the metastable states $O_2(a^1\Delta_g)$ and $O_2(b^1\Sigma_g^+)$ in oxygen discharges in particular at higher pressures.

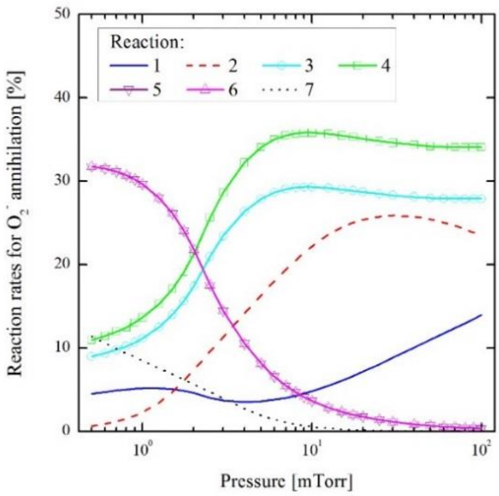

Figure 1. Reaction rates for O_2^- annihilation as a function of pressure for a stainless steel cylindrical chamber.

Table 1. Main reactions for O_2^- annihilation.

No.	Reaction
1	$O_2^- + O_2(a^1\Delta_g) \rightarrow e + O_2(X^3\Sigma_g^-) + O_2(X^3\Sigma_g^-)$
2	$O_2^- + O_2(b^1\Sigma_g^+) \rightarrow e + O_2(X^3\Sigma_g^-) + O_2(X^3\Sigma_g^-)$
3	$O_2^- + O(^3P) \rightarrow O_2(X^3\Sigma_g^-) + O^-$
4	$O_2^- + O(^3P) \rightarrow e + O_3$
5	$O_2^- + O_2^+ \rightarrow O_2(X^3\Sigma_g^-) + O_2(X^3\Sigma_g^-)$
6	$O_2^- + O_2^+ \rightarrow O(^3P) + O(^3P) + O_2(X^3\Sigma_g^-)$
7	$O_2^- + O^+ \rightarrow O(^3P) + O_2(X^3\Sigma_g^-)$

References

[1] D. A. Toneli, R. S. Pessoa, M. Roberto, and J. T. Gudmundsson. *J. Phys. D: Appl. Phys.* **48** (2015) 325202.

[2] D. A. Toneli, R. S. Pessoa, M. Roberto, and J. T. Gudmundsson. *J. Phys. D: Appl. Phys.* **48** (2015) 495203.