Neutral and ion kinetics in glow discharges of H\textsubscript{2}/O\textsubscript{2} mixtures. 
Diagnostics and modelling

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Abstract

Low pressure plasmas with H\textsubscript{2} and O\textsubscript{2} are of interest in a variety of fields, such as astrophysics \cite{1}, discharge cleaning of vacuum vessels in fusion research \cite{2}, or surface treatment \cite{3}. In this work, H\textsubscript{2}/O\textsubscript{2} plasmas generated in a hollow cathode discharge at 8 Pa, spanning the whole range of mixture ratios, are studied. Neutral and positive ion distributions are measured by mass spectrometry. Langmuir probes provide charge densities and electron temperatures. As expected, apart from the neutral precursors, H\textsubscript{2}O is detected in considerable amounts. The ion distributions are dominated by H\textsubscript{3}O\textsuperscript{+} for most O\textsubscript{2} initial proportions (5\%<O\textsubscript{2}<70\%). H\textsubscript{2} and O\textsubscript{2}\textsuperscript{+} are the major ions for O\textsubscript{2}<5\% and O\textsubscript{2}>70\%, respectively.

A zero order kinetic model has been developed to explain the experimental results. H\textsubscript{2}O is produced via plasma-surface interactions in a multistep process. The positive ion distributions are determined in each case by a balance between the relative weights of electron impact processes and proton transfer chemistry. Estimations of negative ion concentrations predict that they represent globally less than 10-20\% of the total negative charge in all the cases.

Experimental Setup

PLASMA GENERATION

The hollow cathode discharge reactor is described elsewhere \cite{4-6}.

DIAGNOSTIC TECHNIQUES

Neutral species were sampled with a mass spectrometer located in a differentially pumped vacuum chamber. A plasma probe monitor was used for the detection of ions. Double Langmuir probes were used to determine the electron temperature and charge density.

Fig. 1 Experimental Set-up

Experimental Results

Fig.2 Relative concentrations of stable neutrals with discharge on, as a function of the initial O\textsubscript{2} fraction.

H\textsubscript{2}O\textsubscript{2} is formed in noticeable amounts through heterogeneous reactions at the reactor walls, with maximum concentration for initial O\textsubscript{2} ~ 40\%.

Fig.3 Relative concentrations of positive ions.

The three purely hydrogenous ions decrease quickly with growing O\textsubscript{2} initial content. H\textsubscript{2} is present in relatively large amounts only for the lowest O\textsubscript{2} concentrations.

Over most of the mixture proportions (O\textsubscript{2}<70\%), H\textsubscript{3}O\textsuperscript{+} is the major ion, decreasing markedly for the highest O\textsubscript{2} concentrations, where the chemistry is dominated by the two purely oxygenic ions, O\textsubscript{3}\textsuperscript{+} and O\textsuperscript{2+}. The mixed ions OH\textsuperscript{+}, H\textsubscript{2}O\textsuperscript{+} and O\textsubscript{2}H\textsuperscript{+} appear in low concentrations with stable values through the different mixtures, except for the extreme ones, where they obviously sink.

Fig.4 Charge density and T\textsubscript{e} (Maxwellian) measured with a double Langmuir probe

Model Simulations

Fig.5 Predicted concentrations of stable neutrals. They show good agreement with the experiment.

Fig.6 Predicted concentrations of all the neutral species.

Fig.7 Predicted concentrations of positive ions. The tendencies in the ion proportions are reasonably well reproduced by the model. As the O\textsubscript{2} fraction grows, discrepancies between model and experiment become more evident. Major species are sufficiently well reproduced with the exception of H\textsubscript{3}+, which decreases with O\textsubscript{2} concentration far more quickly than observed experimentally.

Fig.8 Predicted concentrations of negative ions. The three negative ions (H\textsubscript{2}, O\textsuperscript{-} and OH\textsuperscript{-}) are at most ~ 10-20\% of the total negative charge. They have a limited impact in the chemistry. Their main contribution is to decrease the electron densities available for electron impact processes.

Summary and Conclusions

- H\textsubscript{2} + O\textsubscript{2} plasmas at 8 Pa for all H\textsubscript{2}/O\textsubscript{2} ratios have been experimentally studied and modelled.
- The neutral chemistry is dominated by the two precursors and H\textsubscript{2}O, which is formed through surface processes.
- The ion composition changes with the mixture ratio, being dominated by H\textsubscript{2}O at low O\textsubscript{2} fractions and by pure oxygenic ions at higher ones.
- The tendencies in the observed behaviors of the stable and ion species are reasonably reproduced by the kinetic model.

References