Topic number 5, 8

# The $NH_3$ plasma transition into "ion-ion" or transient H-E plasma mode

J. Brcka

*TEL Technology Center, America, LLC, US-Technology Development Center, Austin, TX 78741, U.S.A.*

2D plasma fluid modelling was used to investigate a transient development of the ammonia ($NH_3$) gas and to determine transient decomposition in high-density plasma produced by a linear inductively coupled plasma (ICP) source. The inclusion of a large number of reactions (103) considering 31 species and including multiple negative ions results in an expulsion of the electrons from the source domain at constant power. Transient development of the discharge demonstrated a lower electron density than in an electropositive (Ar) plasma. Within 60-100 μs the electron density collapses leading to almost electron-free plasma (for t>1ms). The conditions and geometry of the source explored in this study could lead to steady ion-ion plasma formation with $H_2$ and $N_2$ being the dominant conversion products.

## 1. Introduction

Under specific conditions, electronegative gases are able to generate almost electron-free (ion-ion) plasmas [1,2]. In this simulation study, we investigated ammonia ($NH_3$) gas decomposition by linear inductively coupled plasma (ICP). The aim is to determine the transient behaviour and spatial distribution of all charged species and radical fractions in the $NH_3$ radical source.

## 2. Modelling approach

The feasibility study was performed by a computational plasma fluid 2D model that was constructed in 2D space by using a commercial finite-element multiphysics modelling tool. A more detailed description can be found in Refs. [3,4].

## 3. Results

The model (originally tested in argon) was implemented for the $NH_3$ gas [3]. Addition of the recent dissociative electron attachment (DEA) cross sections [5] emphasized electronegativity in the plasma. This led to a collapse of the plasma either due to (a) the expulsion of the electrons forming an ion-ion plasma, or (b) decoupling from ICP power by transient H-E transition or (c) insufficiently described $N_2$ reaction schemes. Further analysis indicated that the initial reaction scheme overestimated the electron generation rate due to assumptions on the ionization from excited states of considered $NH_3$ and $H_2$ molecules. That possibly led to more frequent DEA collisions under added new reactions that were leading to $NH_2^-$ and $H^-$ ions. Since, the efficiency of the energy transfer through electrons was reduced - the H-E transition is triggered and plasma collapses into an electrically neutral (ion-ion) plasma formation. Under these conditions the $NH_3$ converts dominantly into $N_2$ and $H_2$ fractions. To maintain again an electron driven plasma - an RF power increase is necessary. The transient concentrations of all species are plotted in Fig. 1.

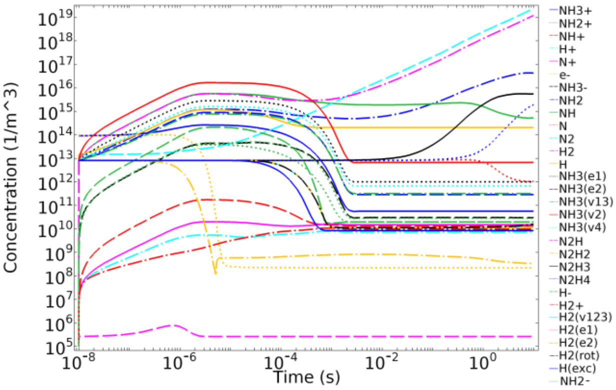


Fig. 1. The transient profiles of charged particles, radicals and neutrals in $NH_3$ plasma source (90 Pa).

## 4. Conclusions

The composition and transient reaction pathways in $NH_3$ plasma are driven by energy transfer efficiency to electrons that are coupled to sustained plasma mode. Recombination processes may lead to conversion into dominant neutral fractions ($N_2$ and $H_2$).

## 3. References

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