Population Inversion in a Magnetized Expanding Thermal Plasma

O. Gabriel, W.J. van Harskamp, D.C. Schram, M.C.M. van de Sanden, R. Engeln

Department of Applied Physics, Plasma and Materials Processing,
Eindhoven University of Technology, The Netherlands

A weakly magnetized expanding hydrogen plasma is investigated by means of optical emission spectroscopy and laser induced fluorescence (LIF) in the vacuum UV. The emission of the expanding plasma jet is dominated by the red H_α emission in the first centimeters from the exit of the source, but changes to blue at larger distances from the exits due to higher Balmer lines (n > 4). Moreover, higher electronic states (n > 4) of H atoms become stronger populated than the lower states [1]. The reaction pathway proposed for the formation of these highly excited hydrogen atoms is via mutual recombination of positive (H_2^+) and negative ions (H^-). The latter are formed by dissociative attachment of electrons with ro-vibrationally excited hydrogen molecules. The ro-vibrationally excited hydrogen molecules are formed at the surfaces of the plasma reactor. Recently the idea that H_2^{rv} acts as precursor for H^- ion formation has been reviewed [2].

In Fig. 1 a diagram of the H^- and D^- production through dissociative attachment of H_2^{rv} and D_2^{rv} is shown. For the calculations we assumed H_2^{rv} and D_2^{rv} density distributions that were measured at 8 mm from the exit of the cascaded arc plasma source by LIF in the VUV. The following experimental conditions were used: 100 Pa background pressure in the plasma reactor, gas flow of 1500 sccm H_2 and 1500 sccm D_2 through the arc, a total input power of 7.5 kW (no magnetic field applied). T_e and n_e are assumed to be 1000 K and 10^{17} m^{-3} respectively. Both were determined in previous measurements. It clearly shows the strong dependence of the negative ion production on the internal excitation of the molecule (note the logarithmic scale of the y-axis).

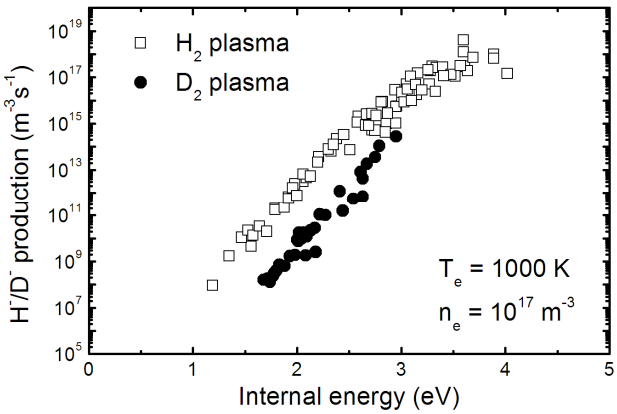

Figure 1. The H^- and D^- production as determined from the measured $H_2^{r,v}$ and $D_2^{r,v}$ density distribution

It is the combination of high densities of highly excited molecules and at the same time a low electron temperature (and thus high DA rate) in the plasma expansion, that creates optimal conditions for negative ion production.

References

[1] J.J.A. van den Dungen, O. Gabriel, H.S.M.M. Elhamali, D.C. Schram, R. Engeln, *IEEE Transactions on Plasma Science* (accepted for publication in August 2008 issue)
[2] M. Bacal, *Rev. Sci. Instrum.* **79**, 02A516 (2008)

Corresponding Author: Richard Engeln
r.engeln@tue.nl
Eindhoven University of Technology
Eindhoven, The Netherlands
T +31.40.2475786, F +31.40.2456442