Influence of dissociative recombination of Hg2+ on an inductively coupled Ar-Hg discharge

Yang Liu, Yuming Chen
Institute for Electric Light Sources, Fudan University; 220 Handan Road, Shanghai 200433, China
yumingchen@fudan.edu.cn

Georges Zissis
LAPLACE (Laboratoire Plasma et Conversion d'Energie) Universite Paul Sabatier - Toulouse III Build. 3R2; 118 rte de Narbonne F-31062 Toulouse Cedex 9; FRANCE
georges.zissis@laplace.univ-tlse.fr

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This paper describes an important effect of Hg_2^+ on the skin effect in an inductively coupled Ar-Hg discharge. A 2D plasma model coupled with the Maxwell equations is utilized for the analysis. The model includes all important plasma chemical reactions and loss mechanisms of particles. Plasma reactions rates are calculated based on the assumption that the electron energy distribution function (EEDF) is Maxwellian. Electron loss caused by dissociative recombination (DR) is expressed as $K_{DR}n_e n\_Hg_2^+$, where K_{DR} is the reaction rate, $n\_Hg_2^+$ is number density of the Hg_2^+ ion and n_e is electron density. Very few publications on $n\_Hg_2^+$ in discharge plasma exist to the best of our knowledge. However, this can be indirectly obtained by estimating the reaction cross sections. According to Ref. 1, the average cross section of associative ionization (AI) is about one fifth of the average chemi-ionization (CI) cross section. That means about one Hg_2^+ is produced in every five CI reactions. In the present model, we assume that CI is responsible for 10%, 20%, and 50% of total electron production. Then, $n\_Hg_2^+=\alpha n_e$, where α=0.02, 0.04, and 0.1. Therefore, the loss term becomes $K_{DR}n_e^2$. According to Ref. 2 and Ref. 3, K_{DR} is on the order of 10^{-13} m^{-3}/s. Here we use 3×10^{-13} m^{-3}/s. Simulation reveals that even with small amount of Hg_2^+, discharge will not become constricted. Furthermore, different densitis of Hg_2^+ do not significantly affect spatial distribution of the electric field. But density of excited Hg atoms is affected. As Hg_2^+ density increases, the density of Hg 6 $^3P_1$ atoms decreases due to smaller rates of excitation caused by rapid loss of electrons. Therefore, DR can be considered as an important mechanism of preventing the discharge from getting constricted. What we should note is that our model is based on a Maxwellian EEDF. Once non-Maxwellian EEDF is applied, frequent excitation and ionization of atoms caused by discharge constriction may quickly drain electrons with high energy. As a result, the process of discharge contraction can be stopped. Thus, depletion of high energy electrons may also be a factor to reduce discharge constriction.

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