O_2 dissociation in plasma and problem of O_2 cross sections set

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DC glow discharges in pure O_2 in a Pyrex tube were studied to determine dissociation rate constant over a wide range of E/N and thereby to probe O_2 dissociation cross section close to threshold. Electric field, E, was found from probe measurements while the gas density, N, from the gas temperature derived from the $O_2(b^1\Sigma_g^+) \rightarrow O_2(X^3\Sigma_g^-)$ emission spectrum. O atom density (as well ratio O/N ratio) was measured by HR TALIF while O/N ratio was also determined by Ar actinometry. Time-resolved actinometry of partially-modulated discharges was used to probe the O loss rate. The O_2 dissociation rate constant was determined as a function of E/N, and compared to calculations from different O_2 cross section sets. This comparison allowed validation of a the self-consistent cross section set for O_2.

1. Introduction

Chemical activity of oxygen plasma is mainly provided by odd oxygen (O atoms and ozone). O_2 dissociation by electron impact is the main channel of O atoms production, therefore the O_2 dissociation cross section, together with electron energy distribution function define the chemical efficiency of oxygen plasmas. Nevertheless, the cross-section for electron impact dissociation of molecular oxygen is the subject of active debate, especially near threshold. The available experimental cross sections near the threshold predict a much lower dissociation rate than that observed. Furthermore, O_2 dissociation is an important electron energy loss channel, influencing electron transport. Cross section sets consistent with observed transport coefficients require an unrealistically high value of the O_2 dissociation cross section. This motivated a study of the dissociation rate constant to validate the near-threshold dissociation cross section and, indirectly, the self-consistent cross sections set for O_2.

2. Experiment

Time-resolved absolute density measurements are needed to probe O atoms kinetics. The measurements were carried out in DC glow discharge in pure O_2, generated in water-cooled Pyrex glass tube of 2 cm diameter and ~50 cm length. The discharge current was controlled by a large (68kΩ) ballast resistor, and could be modulated (5-15%) by shunting a smaller resistor installed between the discharge and ground. The electric field was found from probe measurements, and the gas density was calculated using the gas temperature deduced from the $O_2(b^1\Sigma_g^+) \rightarrow O_2(X^3\Sigma_g^-)$ emission spectrum. The O atom density and O/N ratio was measured by the HR TALIF method while the O/N ratio was also determined from actinometry using Ar atoms. Time-resolved actinometry in partially-modulated discharges was used to probe the loss rate of O atoms.

The O_2 dissociation rate constant as a function of E/N, calculated from the balance between O loss and production rates is shown in figure 1.

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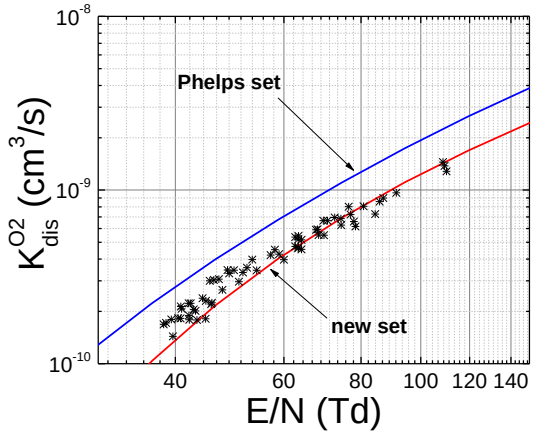

Figure 1. O_2 dissociation rate constant as a function of the reduced electric field E/N.