Understanding the electron and vibration kinetics in CO_2 plasmas

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This work contributes towards a detailed CO_2 kinetic scheme that describes the input and relaxation of vibrational energy in CO_2 plasmas. The vibrational energy exchanges in CO_2 discharges and post-discharges are investigated through a self-consistent model describing the time evolution of the population of individual vibrational levels of the $CO_2(X^1\Sigma^+)$ molecule. The different processes taken into account include the electron-vibration (e-V), vibration-vibration (V-V) and vibration-translation (V-T) energy exchanges. The model was validated by comparing the calculated densities of vibrationally-excited CO_2 molecules with experimental data obtained in a pulsed CO_2 glow discharge.

1. General and model description

The growing interest to plasma-based greenhouse gas decomposition requires the knowledge of the different kinetic mechanisms inherent in CO_2 discharges and post-discharges. To this purpose, we developed a kinetic scheme to describe the time-resolved densities of several CO_2 vibrational levels. More specifically, the rate balance equations for the creation and loss of the levels are investigated. The different processes taken into account include electron-vibration (e-V), vibration-vibration (V-V) and vibration-translation (V-T) energy exchanges. As a starting point, we have assumed a low excitation regime in which only a few CO_2 vibrational levels are excited, such as in pulsed discharges at low specific energy input and short pulse durations [1].

2. Results and discussion

To validate our model, the calculated concentrations of the CO_2 vibrational levels were compared with the experimental densities (obtained via time-resolved *in situ* Fourier Transform Infrared spectroscopy) in a low-pressure pulsed CO_2 DC glow discharge. The system under analysis operates with pressure p = 5 Torr, current I = 50 mA and a pulse width of 5 ms. More details about the experimental setup are given in [1]. As illustration of this analysis, Fig. 1 shows the calculated and measured results of the relative densities of the first vibrationally-excited CO_2 levels associated to the bending vibrational mode ν_2 during the afterglow of the pulsed discharge. As one can see, there is a very good agreement between the calculated and experimentally determined densities, which is also extended to the population of the vibrational levels in the other modes and to the active discharge phase (not shown here).

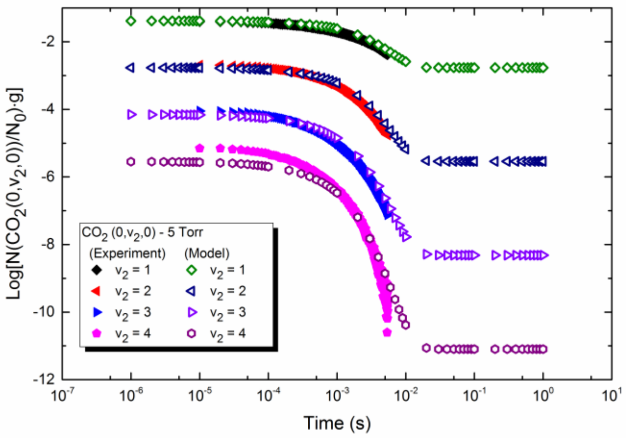

Fig. 1: Normalized density of the first CO_2 bending states during the afterglow of a pulsed DC discharge. Open symbols represent the calculations, while closed symbols the experimental data. N_0 and g represent the ground state density and statistical weight, respectively.

3. Acknowledgments

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4. References

[1] B.L.M. Klarenaar, R. Engeln, M.A. Damen, et al., contribution submitted to ICPIG, (2017).