Measurement of atomic oxygen densities and their transport using TALIF and SEA in a micro cavity array reactor for catalysis

M. Böke[1], D. Steuer[2], H. van Impel[2], R. Labenski[2], B.Z. Bentz[3], K. Youngman[3],
V. Schulz-von der Gathen,[1] and J. Golda[2]

[1]*Physics of Reactive Plasma, Ruhr-University Bochum, GERMANY*
[2]*Plasma Interface Physics, Ruhr-University Bochum, GERMANY*
[3]*Sandia National Laboratories, Albuquerque, USA*

Abstract: This work investigates the production of atomic oxygen and its transport out of the micro cavities of a plasma array mainly by means of TALIF and helium state enhanced actinometry. Atomic oxygen often plays a central role or may act as a model for more complex species in plasma catalytic processes. We found very efficient dissociation in the cavities whereas the transport is dominated by diffusion and losses due to ozone generation.

1. Introduction

Micro-structured plasma discharge cavity devices show great potential for applications requiring large-area treatment, catalytic conversion, or decomposition of volatile organic compounds. Therefore, arrays of dielectric barrier micro discharges in well-defined cavities are of high relevance from a scientific and technical point of view. To understand the underlying processes, fundamental knowledge about the discharge dynamics and generation of reactive species (here: atomic oxygen) is necessary. Additionally, the impact of fluxes of (charged) particles driven by electric fields and plasma-induced surface charges on catalysis are of high interest.

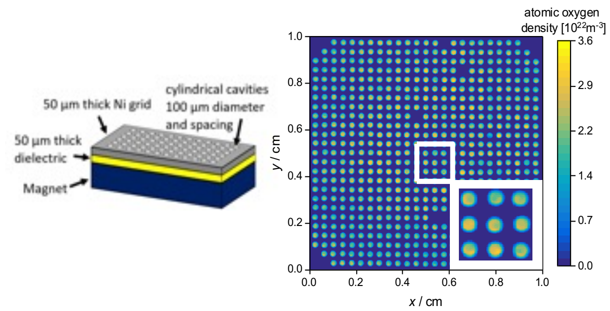

Fig. 1. MGA and atomic oxygen density

2. Methods

In this work, we investigate modular constructed metal-grid micro cavity [1] plasma arrays (MGA) which allow for stable operation and the incorporation of catalysts (see Fig. 1 left). MGAs consist of hundreds to thousands of discharge cavities with ~100µm dimensions and are operated in helium with admixtures of reactive gases, typically in the percentage range (excitation: kHz triangular voltages of 400-800V). However, diagnostics in these cavities are challenging due to their small dimensions. The basic discharge behavior like discharge mode and expansion, electrical characteristics and dynamics will be discussed and accompanied by optical emission-based methods to determine electric fields (Stark shift) [2] and 2D resolved atomic oxygen densities inside (by helium state enhanced actinometry (SEA)) and two-photon absorption laser induced fluorescence (TALIF) outside the MGA [3,4].

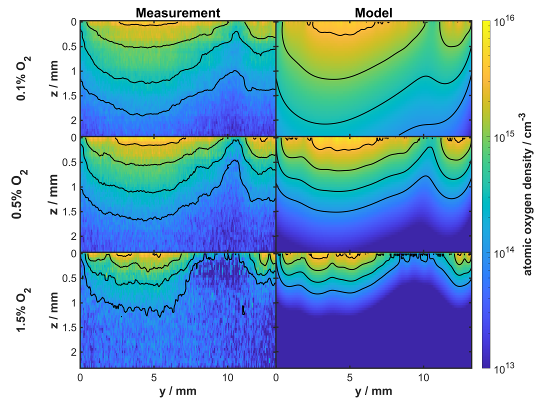

Fig. 2. Atomic oxygen density outside the MGA

3. Results and Discussion

Atomic oxygen densities in the volume inside and above a micro cavity plasma array are successfully determined spatially and time-resolved using SEA and TALIF measurements and explained by a basic model. Fig. 1 (right) shows spatially resolved atomic oxygen densities measured by SEA of a whole MGA. Inside the cavities nearly complete dissociation of O_2 is achieved. Fig. 2 shows TALIF measurements and results of a basic diffusion model outside the MGAs. Slightly outside an equilibrium density is reached after 3ms. Regions further away are dominated by diffusion and ozone formation. SEA findings can be linked to the TALIF measurements outside via the model. An optimal dissociation is found at 0.4% oxygen admixture, where there is a balance between production inside the cavity and losses outside.

Acknowledgement

This work is supported by the DFG within SFB1316 & GSC98/3 and by DOE FES DESC0020232 and Sandia's Plasma Research Facility (DOE NNSA: DE-NA0003525).

References

[1] S. Dzikowski et al., PSST **29** 035028 (2020)
[2] H. van Impel et al., PSST **33** 105008 (2024)
[3] D. Steuer et al., PSST **32** 025013 (2023)
[4] D. Steuer et al., PSST **33** 125007 (2024)