Oxidizing species in late Ar-O_2-N_2 afterglow for bacterial treatment

Cédric Noël[1], Kinga Kutasi[2], Thierry Belmonte[1]

[1] *Institut Jean Lamour, CP2S Department, University of Lorraine, CNRS, Parc de Saurupt, CS 14234, F-54042 Nancy Cedex, France*
[2] *Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Hungarian Academy of Sciences, POB 49, H-1525 Budapest, Hungary*
E-mail: cedric.noel@ijl.nancy-universite.fr

Afterglows are soft media which are known since the precursor works of Moreau *et al.* [1] as anti-bacterial media. Ar-N_2-O_2 afterglows were shown to be more efficient than Ar-O_2 post-discharges, mainly because of the UV emission produced by NO* emission [2]. If the role of oxygen atoms, NO molecules and photons has been carefully described, late Ar-N_2-O_2 afterglows still need to be characterized carefully. Theoretical approaches [3, 4] have been recently developed to gain understanding in reaction pathways leading to the synthesis or removal of active species. However, experimental data are to be produced to confirm the predicted behaviors.

Different tools are commonly used for the diagnostics of excited species. For ground state, metastable and radical species, one must resort to sophisticated techniques such as laser absorption, laser induced fluorescence, cavity ring down spectroscopy, Fourier transform infra-red spectroscopy, which are either poorly sensitive techniques or techniques dedicated for the study of specific species. Threshold ionization mass spectrometry technique allows us determine the nature and the densities of different active species.

In this work, we used the combination of optical emission spectroscopy and ionization threshold mass spectrometry to characterize an $Ar_{1-x}/(O_{2\ 1-y}/N_{2\ y})_x$ ($0 \leq x \leq 0.1$ and $0 \leq y \leq 1$) microwave afterglow (total flow rate: 200 sccm) from 1 to 10 mbar. It turns out that the determination of the concentration of oxygen-containing species is difficult to achieve, because of several artifact of measurements (dissociation of species on hot filament, filament oxidation, high control of impurity levels, etc.)

We could get reliable results on O, NO, N_2O, N, N_2, O_2 by mass spectrometry in a 5 mm inner diameter fused silica tube. For instance, for x=0.1 and y=0.5, an absorbed microwave power of 100 W and a flowing time in afterglow corresponding to ~5.2 ms, we determined at 5.6 mbar: [O]=1.85 × 10^{14} cm^{-3}, [NO]=1.77 × 10^{14} cm^{-3}, [N_2O]=3.04 × 10^{14} cm^{-3}, [N]=3.17 × 10^{12} cm^{-3}, [N_2]=5.72 × 10^{15} cm^{-3}, [O_2]=5.11 × 10^{15} cm^{-3} and [Ar]=1.06 × 10^{17} cm^{-3}. The gas temperature is 345 ± 27 K. By optical emission spectroscopy, we could follow the green emission of the NO_2* → NO_2 transition centered at 550 nm that immediately appears as soon as nitrogen is introduced in Ar-O_2 discharges. Finally, a first comparison with theoretical results could be made.

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