Optical emission spectroscopic evaluation of different microwave discharges and its potential application for sterilization processes

J.L. Hueso[1,2], V.J. Rico[1], A. Yanguas-Gil[1,4], J. Cotrino[1,3], A.R. González-Elipe[1]
[1]*Instituto de Ciencia de Materiales de Sevilla. Avda. Américo Vespucio 49, 41092 Sevilla. (Spain)*
[2]*Departamento de Química Inorgánica de la Universidad de Sevilla (CSIC-Univ. Sevilla)*
[3]*Departamento de Física Atómica, Molecular y Nuclear de la Universidad de Sevilla.*
[4]*Current Address: Argonne National Laboratory (IL, USA)*
e-mail: jhueso@icmse.csic.es

Résumé

The present work aims at studying different microwave flowing discharges containing Ar or N_2 as main carrier gases by Optical Emission Spectroscopy (OES) to demonstrate the potential possibilities of these plasma mixtures to provide O^* and UV species demanded for sterilization purposes at low temperatures. The influence of additional reactants such as NO and/or O_2 is also evaluated. Additionally, some plasma sterilization results with *E. coli* cultures are presented.

Introduction

Plasmas are currently used for the sterilization of heat-sensitive medical tools and the inactivation of bacteria and/or spores. The high energy capabilities at relative low temperatures and costs in conjunction with simple reactor designs make plasmas as a promising alternative to heating or chemical methods (i.e. ovens, autoclaves, EtO oxidation). In recent years, different type of discharges containing inert gases, O_3, O_2, N_2, CO_2, H_2O_2 or mixtures of them have been used with reasonably good results [1-7]. More recent investigations have demonstrated the synergetic role of O* and UV photons [4]. Low-moderated pressure plasmas permit the co-existence of UV photons and atomic atoms what has been reported as a synergetic effect by Moisan et al [1-2]. In contrast, under higher pressures and thus with higher collision frequencies in the atmospheric conditions, a great part of the charged and excited species are recombined with carrier gas atoms.

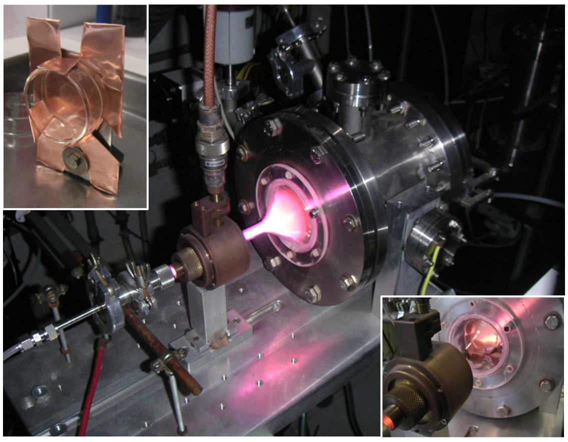
The aim of the present work consists of a thorough study of microwave (MW) plasma discharges containing different carrier gases such as Ar or N_2 and the influence of the addition of other reactants like NO and/or O_2. These plasma discharges are evaluated by in situ Optical Emission Spectroscopy (OES) in order to identify the main reactive intermediates and the best candidates to provide O and UV species demanded for sterilization process [7-9, 12]. Additionally, some in vitro sterilization results on *E. coli* cultures are shown for selected plasma mixtures.

Experimental

The experimental setup to generate the microwave consists of a quartz tube reactor of 3.5 mm of inner radius with a funnel-type ending and coupled to a surface-wave surfatron launcher which permits the transformation of the electromagnetic power to the travelling wave and the propagation of the plasma discharge (see Figure 1). The MW discharges are produced in a moderated pressure range between 30 and 90 torr, although the presented results are referred to 45 torr. Ar or N_2 were fed through calibrated mass flow controllers as carrier gases with a total flow of 50 cm^3 min^{-1}. The concentration of NO and eventually O_2 were kept constant at 3 x 10^3 ppm and 3×10^4 ppm respectively. Axial profiles along the x-axis of the quartz reactor at different points from the gap discharge have been obtained for Ar-NO-(O_2) and N_2-NO-(O_2) plasma discharges. The OES spectra have been registered by collecting the light with an optical fiber connected to a scanning monochromator (Jobin-Ybon HR250) and a Hamamatsu photomultiplier (R928). *E. coli* DHα were grown in a LB medium at 37 ºC for 24 hours. Cells were washed thoroughly prior to any plasma treatment and the colony forming units were determined by the viable count method [11].

Results and Discussion

The addition of NO into Ar or N_2 yielded different UV emitting species as detected by OES (see Figure 1) thereby indicating different excitation channels for Ar (atomic gas) and N_2 (molecular gas) [7-9]. The presence of Ar also demonstrated to keep plasma discharges stable for a longer range from the resonant cavity in comparison with N_2. Therefore, Ar sustained plasmas can be considered more suitable for sterilization purposes where the maximum extension of the cleaning chamber should be exposed. The systematic addition of increasing amounts of O_2 was found detrimental in terms of total volume of discharge but positive for the generation of additional O^* radicals and the recombination of dissociated NO^* species. Similar sterilization results were found after comparing Ar-NO, N_2-NO and N_2-O_2 mixtures although slightly superior for the former plasma combination.



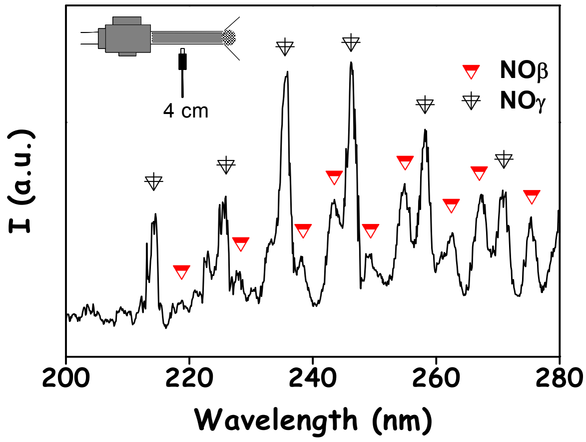


Fig. 1: (Left): Microwave plasma reactor used for the sterilization experiments. The insets show further details about the culture dish holder and its interaction with the plasma discharge generated by the surfatron launcher during an *E. coli* sterilization experiment; (Right): Optical Emission Spectrum corresponding to the UV species generated in a plasma discharge containing Ar-NO.

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