Transmission through hollow tubes of N-atoms produced by N_2 and Ar-1%N_2 flowing microwave afterglows

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Transmissions of N-atoms through dia.3 mm silica tubes and through dia.1.5 mm stainless steel tubes have been measured in N_2 and Ar-N_2 afterglows of microwave discharges. The tube wall γ-destruction probabilities of N-atoms have been deduced: $\gamma = (1\text{-}1.6)10^{-3}$ for the silica tube and $\gamma = (1.6\text{-}2)\ 10^{-2}$ for stainless steel tube.

Transmissions through hollow tubes of N-atoms produced in N_2 and Ar-N_2 afterglows are measured. The production of N-atoms is studied in flowing microwave post-discharges at medium gas pressures (1-30 Torr) and power of 100-300 Watt in the plasma. The plasma is located inside a quartz tube of int.dia. (i.d) 5 mm and 30 cm length. It extends along a few centimeters outside the cavity (surfatron) gap for a gas pressure between 1 and 30 Torr and a flow rate between 0.5 and 2 slm. The discharge tube is connected to a tube of 18 mm i.d and 30 cm length setup before a 5 litre post-discharge reactor. At a pressure of 5 Torr and a flow rate of 1 slm, the flow times are calculated as being 2 10^{-3} sec and 10^{-2} sec in the tubes of 5 mm i.d and of 18 mm i.d., respectively. A Teflon junction connects the 18 mm tube to the 5 litre reactor. After the plasma, the early and late afterglows appear and the late afterglow extends in the post-discharge reactor where the sterilization of bacteria are studied.

Bacteria inactivation by N-atoms in such post-discharge reactor has been largely studied [1-3]. The results obtained for the transmission of N-atoms produced in N_2 and Ar-N_2 late afterglows through hollow tubes are presently reported. These studies are of interest to appreciate the possibility of N-atoms sterilization inside hollow silica and stainless steel tubes.

The emission spectroscopy is performed by moving an optical fiber from the plasma gap to the external wall of the post-discharge reactor.The N atom density is obtained by NO titration [4] by injecting an Ar-2%NO gas mixture in the post-discharge tube. The transmissions of N-atoms through hollow tubes were studied by using the Teflon junction of the 18 mm tube. Teflon junctions were worked to receive between 3 to 9 tubes of dia. 1-3 mm across it. The insertion of hollow tubes in the Teflon junction produces pressure variations between the plasma tube and the 5 litre reactor. Such pressure variations were analysed from the afterglow emissions before the Teflon junction by keeping a given pressure in the 5 litre reactor. At a too high N_2 pressure (p> 10 Torr) , it was difficult to switch on the N_2 plasma at power less than 300 Watt. Adding Ar to N_2 allows to obtain a stable discharge from low pressure up to atmospheric gas pressure with N_2 percentage below 23% with a microwave power limited to 300 Watt [5].

By using a Teflon tap with 3 holes of dia.4 mm, 3 silica tubes of i.d. 3 mm and outside dia.(o.d.) 4 mm, of length from 80 to 250 cm, are connected. The N_2 plasma was switched on at 300 W , 1 slm , 4 Torr. The N-atom transmission (T_N) was found to be T_N = 35% at 9 cm and T_N = 8.5 % at 80 cm for a N-atom density before the Teflon junction of 4.2 10^{15} cm^{-3}.

To improve the plasma lighting at high flow rate and at high gas pressure, it was experimented an Ar-1%N_2 gas mixture. Then the plasma was obtained at 150W , 3slm , 20 Torr in the 5 litre reactor , with the 3 tubes of i.d 3 mm and length 80 cm. The N-atom density before the Teflon tap was found to be 8.2 10^{15} cm^{-3} and T_N = 8.5 % at 80 cm, that is an increase of 3 of N-atom density and the same T_N value in comparison to N_2 300 W , 1 slm .

Stainless steel tubes of i.d 1.5 mm and o.d 2 mm , of length 6.5 cm were located across a tap of the Teflon junction with 9 holes of dia.2 mm. A N_2 microwave plasma was obtained at 300 W , 1 slm and 1.7 Torr in the 5 litre reactor. In these conditions, the N atom density was 8 10^{15} cm^{-3} before the Teflon junction and decreased sharply to about 10^{14} cm^{-3} at the exit of the 9 stainless tubes of length 6.5 cm, that is a N-atom transmission T_N = 1.3 %.

By estimating that the main loss of N-atoms is by collisions on tube wall with a γ-destruction probability, it has been determined $\gamma = (1\text{-}1.6)10^{-3}$ for the silica tubes and $\gamma = (1.6\text{-}2)\ 10^{-2}$ for the stainless steel tubes. The γ- values are in good agreement with published values for the silicon tubes : $\gamma = 3\ 10^{-3}$ for Nylon at 2 Torr [6] but not for the stainless steel tubes where $\gamma = 5\ 10^{-3}$ at 5 Torr and $\gamma = 6\ 10^{-3}$ at 3 Torr [7].

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