

Spatial profiles of atomic oxygen concentrations in a large scale CCP reactor

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Nickel catalytic probe was used to measure atomic oxygen concentrations in a large scale cylindrical asymmetrical capacitively coupled plasma reactor. We have measured O concentrations in the main chamber of the reactor as well as in the side tube placed perpendicular to the chamber wall. The spatial profiles in these two regions differ both in magnitude (10^{19} m^{-3} vs. 10^{18} m^{-3} or even 10^{17} m^{-3}) and in the way the concentrations decrease when moving away from the powered electrode. This is explained by the different chamber wall configuration around the probe and its proximity because the grounded walls are also O atom drain due to the recombination. Working gas was air at 300 and 600 mTorr and the power was fixed at 500W.

Low temperature plasmas at sub-atmospheric pressures are an essential tool in many industrial processes due to variety of chemical reactions that can be induced and controlled while maintaining low gas temperatures. Low pressure radiofrequency plasmas are irreplaceable in the semiconductor industry but this is hardly the only field of their application [1, 2]. A large scale cylindrical asymmetrical 13.56 MHz CCP reactor was developed in our laboratory for the purpose of textile, polymer and seeds modification [3, 4]. Sensitive material treatment requires low ion energy bombardment and high concentrations of active species like O. For instance the formation of new oxygen-containing groups on the fiber surface is suggested to be due to the presence of extremely reactive atomic oxygen species in discharge during the air plasma processing and/or post-plasma chemical reactions when the activated fiber surface reacts with environmental species [5]. The asymmetric design of the reactor was chosen to provide low energies of ions bombarding the surfaces of the samples in order to avoid excessive damage of the samples.

We have used nickel catalytic probe positioned side-on to the powered electrode to measure O concentrations in the main chamber and in the small side tube (see Fig 1.).

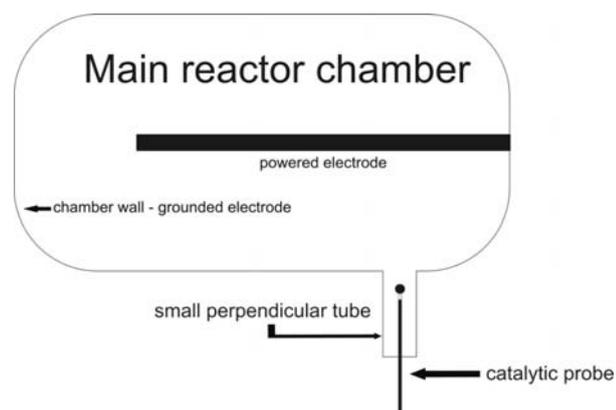


Fig. 1: Catalytic probe position in the reactor.

Detailed experimental setup details can be found elsewhere [6] as well as the design and the operation of the catalytic probe [7, 8]. Measurements are performed in air at 300 and 600 mTorr. The power was fixed at 500 W.

Spatial profiles of O concentrations are shown at Fig 2. We can see that the concentrations are higher at higher pressure and are decreasing faster in the side tube compared to the main chamber when moving away from the powered electrode. This is due to the difference in the vicinity and the area of the grounded wall which is closest to the probe at certain position.

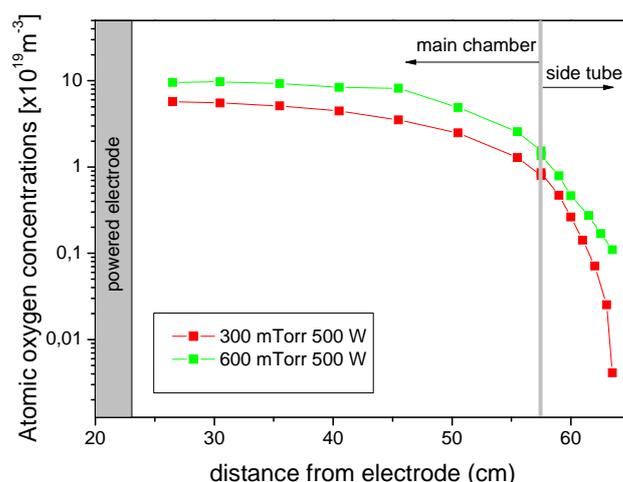


Fig. 2: Atomic oxygen spatial profiles in the main reactor chamber and in the side tube. Working gas was air at 300 and 600 mTorr and the power was fixed at 500 W.

The surface recombination of O atoms is taking place at the surface of both the nickel catalytic probe and at the chamber wall. In the tube, the wall is a stronger O atom drain both because it is closer and because the effective area is larger. By placing the sample at different distances from the powered electrode O concentrations can be controlled in the range from 10^{17} m^{-3} to 10^{19} m^{-3} . Depending on the intrinsic properties of the material being treated and on the modification effects that are desired we can tune the O concentrations at the sample surface simply by putting the sample in one of two regions of the reactor (main chamber and side tube) and adjusting its position. Adjustment can also be achieved by changing the pressure, power and gas composition.

References

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