Diagnosing negative ions using electrical probes

S. K. Karkari[1], A. Pandey[1], N. Sirse[2] and M. Turner[2]

[1] *Institute for Plasma Research, HBNI, Bhat village, Gandhinagar, Gujarat, India, Pin 382428*
[2] *Dublin City University, Glasnevin, Dublin-9, Ireland*

Unconventional application of hairpin and Langmuir probes has been demonstrated to quantify negative ion temperature and density in electronegative plasma. This includes the estimation of negative ion temperature based on floating potential of a cylindrical Langmuir probe and inferring negative ion density by resonance hairpin probe in conjunction with pulse laser photo-detachment method. The underlying principle behind these techniques shall be discussed along with experimental findings of plasma parameters in oxygen discharge.

1. Introduction

Electronegative plasmas are highly popular in semiconductor industries besides being used for producing energetic neutral beams for plasma heating in fusion devices. The negative ions presence in the discharge can dramatically influence the characteristic Bohm speed of positive ions entering the sheath and leaving the plasma boundary. The discharge impedance is also impacted due to negative ions. Thus quantification of negative ion parameters is important for characterization of negative ion sources besides being useful in the fundamental studies of negative ion plasmas in laboratory.

The conventional method to measure negative ion density is achieved by pulse laser photo-detachment technique [1]. This method relies on a detection probe to measure the photo-detachment current signal. Though this serves as a basic tool for the quantification of negative ions, however certain complication arises in magnetized plasmas. In this case, the detection probe when biased to electron saturation current severely depletes the plasma electrons in the magnetic flux tubes attached to the probe surface. Therefore estimates of plasma parameters are affected besides the probe introduce strong perturbation to the plasma.

2. Unconventional probing methods to measure negative ions

To overcome above limitation, unconventional probing methods have been developed based on resonance hairpin and cylindrical Langmuir probes.

2.1. Application of Hairpin probe

The hairpin probe is based on microwave technique and has been used for the detection of negative ions both inside and outside the photo-detachment region [3]. Experimental results have shown that the positive ions in the photo-detached channel are strongly depleted after the pulse laser beam has expired [4]. To address the above issue, a direct method of inferring negative ion parameters by hairpin probe has been developed. The negative ion parameters have been inferred by time modulating the dc sheath around the hair-pin prongs [5] with a train of rectangular voltage pulses applied to the hair-pin probe. Synchronous measurement of electron density provides the information of negative ion parameters around the hairpin.

2.3. Negative ion temperature from floating potential of cylindrical probe

Recently, floating potential of a cylindrical probe have been investigated as a function of electronegative parameters $\alpha = n_- / n_e$ and $\gamma = T_e/T_-$; [6]. A comparison of analytical curves of floating potential as a function of α, with γ as a free parameter enables to calculate T_- by tuning the value of γ to match with the floating potential obtained in experiment. Using this method, the negative ion temperature in oxygen discharge has been found in the range of 0.05 – 0.07 eV at operating pressures of 4.0 – 7.0 Pa.

3. References

[1] M. Bacal. Rev. Sci. Instrum, **71**(11) (2000) 3981

[2] S. K. Karkari, C. Gaman, A. R. Ellingboe. APL. **28** (2008) 071501.

[3] N. Sirse, S. K. Karkari, M. A. Mujawar, J. Conway, M. Turner. Plasma Sources Sci. Technol. **20** (2011) 055003

[4] J. Conway, N. Sirse, S. K. Karkari, M.M Turner. Plasma Sources Sci. Technol. **19** (2010) 065002

[5] N. Sirse, S. K. Karkari, M. Turner. Plasma Sources Sci. Technol. **24** (2015) 022001

[6] A. Pandey, S. K. Karkari. Physics of Plasma, **24** (2017) 013507