Seminar

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Institute for Plasma Research

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Title: Sheath Characteristics of an Electron Emitting Wall in an Electropositive/Electronegative Plasma

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Abstract

When plasma contacts the cathode wall (that acts as beam of electrons emitting source) inside the sheath, then the positive ion space charge gets partially neutralized, and the electrical property of the sheath gets altered. This type of sheath formed is called a double sheath, which was first observed by Langmuir [1]. Amemyia [2] analysed the effect of negative ions on the double sheath. Considering the inertia and the temperature of species the criterion for the presence of stationary sheath containing both charges is formulated by the Shiraishi [1] where it was shown that a double-layer structure is formed inside the sheath in which there is ion-depleted sublayers adjacent to plasma and electron-depleted sublayers adjacent to the charged body. The use of Maxwellian distribution in Boltzmann-Gibbs statistics is valid till the system is in equilibrium. While for system where there is non-equilibrium stationary state exist and the long-range interaction occurs just like in the plasma and gravitational system the Tsallis or Non-extensive statistics gives the more correct explanation of the phenomenon occurring in the system. Hence the concept of non-extensivity is addressed to have a balance condition required for sustaining of the plasma in the system where electron emission also takes place from the wall. To get the role of non-extensivity on double sheath and virtual cathode formation in collisional-less plasma a theoretical model is given where the variation of velocity of positive ions inside the sheath and the sheath edge, the electric potential, space charge density and sheath thickness are analysed for the cases of different non-extensivity q.

Electronegative plasmas, where negative ion species are also present in addition to the positive ions and electrons, are advantageous to be studied because of their various applications due to the enhanced electric field they create in the sheath. It is used in modifications of optical, mechanical and electrical properties of thin films/surface. To modify the specific surface biological property, plasma-based surface treatments are used since a relatively lesser potential is developed compared to that of electropositive plasma. Using electronegative plasmas lesser distortion of the material surface is obtained and the abnormal etching shapes have been avoided. The presence of negative ions in the system improves the performance of materials being used for integrating circuits. Bohm criterion and sheath formation mechanism are evaluated using Sagdeev potential approach in warm electronegative collisional plasma in contact with electron emitting surfaces and having q- non extensively distributed electrons for unmagnetized case. The Bohm sheath criterion is also formulated for electronegative warm plasma under oblique magnetic field and secondary electron emission from the wall. The effect of collisions between positive ions and neutral, ionization, electronegativity, non-extensivity and temperature ratio (positive/negative ion to electron) are also considered to get the exact behavior of velocity of positive ions at the edge of the sheath. Plasma-material interaction is also examined in an electronegative warm plasma under secondary electron emission from the wall where the negative ion is described with fluid equations to see it's effect of

the mass ratio (negative ion to positive ion) on emitted electron beam density inside the sheath. The sheath formed during the interaction is evaluated and its thickness is compared for three different plasmas (C_{60} plasma, Oxygen plasma and CF_4plasma) and the sheath thickness is found to be maximum in C_{60} plasma and minimum in Oxygen plasma. The effect of collisions, ionisation and non-extensivity is studied numerically in an electronegative warm plasma associated with electron emission from the wall.

So having the theoretical background of electronegative plasmas there are various experiments can be performed in IPR. Specially the DC biased harpin resonator probe [4] along with Langmuir Probe present there to find the electronegativity as well as plasma anisothermicity with greater accuracy can be used to get the exact sheath thickness and plasma potential. Considering the temporal variation in the continuity and momentum transfer equation of theoretical model the characteristics of sheath can be understood by also verifying with the experiments.

References

1. I. Langmuir, "The interaction of electron and positive ion space charges in cathode sheaths," *Phys. Rev.*, vol. 33, no. 6, pp. 954–989, 1929.

2. H. Amemiya, B. M. Annaratone, and J. E. Allen, "The double sheath associated with electron emission into a plasma containing negative ions," *J. Plasma Phys.*, vol. 60, no. 1, pp. 81–93, 1998.

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4. Singh, P., & Karkari, S. K. (2022). Equilibrium properties of inhomogeneous partially-magnetized plasma containing negative ions. *Journal of Physics D: Applied Physics*, *55*(23), 235201.