5th Asia-Pacific Conference on Plasma Physics, 26 Sept-1Oct, 2021, Remote e-conference

Fast-Sweeping Langmuir probes: sheath and circuit effects to the I-V traces when the sweeping frequency is higher than the ion plasma frequency

C-S. Yip[1], CY Jin[1,2], W Zhang[1], D Jiang[1], G S Xu[1]
[1] Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China,
[2] University of Science and Technology of China, Hefei Anhui 230026, China
e-mail (speaker): csyip@ipp.ac.cn

Limited particle transit time is one of several limiting factors which determines the maximum temporal resolution of a Langmuir probe. Where various forms of time-resolved Langmuir probe are becoming increasingly common due to the need to explore time-varying plasma phenomena, previous studies claimed that even sweeping at ~1/9 the ion plasma frequency, the I-V trace of a Langmuir probe would be deformed significantly due to effects of limited ion response time.

In this work, we have revisited the two known fast sweep Langmuir probe techniques, namely the high-speed dual Langmuir probe (HDLP) technique and simply minimizing the circuit capacitance and deduct the residual capacitive response from the I-V trace. Special attention was paid to minimize the parasitic capacitance of the probe circuit: all coaxial wires are replaced with single wires, and total wire length of the system is limited to 80cm for the HDLP setup and less than 60cm for the single probe setup. We employed a triangular voltage waveform; therefore, the first order capacitive response is a DC current.

Experiments are performed in a uniform, quiescent multi-dipole confined hot cathode discharge. The quiescent nature of a multi-dipole confined hot cathode discharge allow us to perform experimental studies without the disruption of source related fluctuations. With our usable sweeping frequency is limited to 500kHz, we adjust the plasma density via neutral gas injection and the discharge current to adjust the ion plasma frequency so that it can be reduced below our sweeping frequency. Two experimental scenarios are investigated: one in which the probe sweeping frequencies is much lower than the ion plasma frequency and one which the sweeping frequency is approximately 3 times the ion plasma frequencies, respectively. This allows the investigation of the effect of limited ion-motion on I-V traces to be compared to a “control” scenario where limited ion transit time is expected to be a non-issue.

Circuit related effects, possibly capacitive/inductive response between the voltage formed on the shunt resistance and the rest of the circuit is clearly observed. The effect, interestingly, has limited effect on our measurement results provided that if the shunt resistance is small enough. However, distortions of I-V traces at high frequencies, previously claimed to be ion-motion limitation effect, was not found unless shunt resistance is sufficiently high, this suggests that circuit response remains the dominant effect.

This result essentially is a manifestation of the Langmuir probe as an electron collecting probe. Additionally, techniques in fast sweep Langmuir probe are briefly discussed. The comparison between the HDLP and the single probe setup shows that the capacitive response can be removed via subtracting a load line for the single probe setup almost as effective as using an HDLP setup, but the HDLP setup allows a researcher to better use the limited voltage range of any practical data acquisition systems, allowing a smaller DAQ voltage range to be used as HDLP eliminates much of the DC circuit response which occupies significant proportion of the signal even when the circuit capacitance is extremely minimized like our setup. Thus, HDLP remain advantageous in its facilitation of better recovery of weak current signal common in low plasma density situations.

The authors would like to express their thankful acknowledgement in memory of the late Dr. Noah Hershkowitz, Irving Langmuir Professor Emeritus of the University of Wisconsin – Madison, and a longtime collaborator of the authors who have gave invaluable advice and discussions to our studies associated with sheath/presheath and diagnostics associated physics. The authors would also like to thank Dr. Yevgeny Raitses of the Princeton Plasma Physics Laboratory (PPPL) and Dr. Paul Dourbal at Members Exchange (MEMX) for their helpful discussions on high-speed circuitry. This work is supported by the National Natural Science Foundation of China contract no. 11875285.

References
[1] CY Jin et al., submitted to PSST.

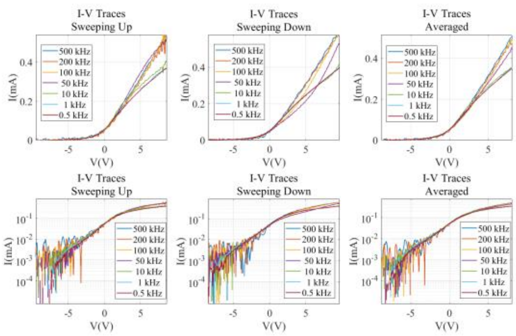

Figure 1. I-V traces at different frequencies of the HDLP setup sweeping up, down and both traces averaged in linear and semi-logarithmic scales in a low density plasma