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An extraction of microwave ECR plasma cathode based e-beam under ultralow pressure

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Comparing to hot cathode electron beams which can't provide the required electron-beam (e-beam) parameters due to limited emissivity and are limited in short operation life, plasma electron sources are able to produce greater emission current density and capable of pulsed mode beam generation. The advantageous features of plasma-cathode e-beam make them attractive for various applications, e.g. e-beam welding and powder cladding, generation of electromagnetic radiation, modification of material surface properties, plasma chemical, neutralizer and radiation technologies. Generally, in order to produce required emission current density, the discharge employed in plasma-cathode electron sources must provide generation of dense plasma in the region of electron extraction. From this standpoint, several suitable kinds of plasma sources for electron extraction are hollow cathode sources, helicon discharges arc discharge plasmas, Penning discharges, and microwave electron cyclotron resonance (ECR) plasmas. In the design of plasma-cathode electrode sources, the emission current density and acceleration voltage in the region of electron-beam formation are required simultaneously. For some applications like e-beam welding the kinetic energy of a single electron is dominant to determine the penetration depth, which demands of higher acceleration electric field. To avoid the breakdown in the acceleration gap the lowest possible pressure is needed due to the Paschen's rule. Microwave ECR plasma sources are capable of generating high density plasmas at gas pressure down to mTorr range. The advantages of high density and low working gas pressure are much attractive for e-beam generations and applications because it is possible to approach higher emission e-beam density and apply higher electric field in the acceleration gap. Max Light et al. presented analyses and characterizations of an ECR driven plasma cathode electron beam source. The beam currents of greater than 80 amperes (A) for bias voltages of minus 100 V at gas pressure of around 0.27 Pa were generated. However, the mean velocity of the e-beam increases slightly from 4×10^6 to 4.6×10^6 m/s as the negative bias is decreased to minus 120 V. In this paper, we present an initial experiment result of e-beam (~75 mA) extracted from a permanent magnet based microwave ECR plasma cathode under conditions of ultralow gas pressure ($\sim1\times10^{-3}$ Pa) and high accelerating electric field (up to 9.5 kV). The presented results may improve the physical understanding of the ECR based e-beam and expand the potential utilization areas in industrial applications

References

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Figure The e-beam current Is vs. (a) working pressure, and (b) microwave power.