MONOCHROMATIC OSCILLATION GENERATED IN A LOW POWER ION MAGNETRON

Noboru Tanizuka

Junior College of Engineering
University of Osaka Prefecture

Abstract: This paper deals with a stable oscillation phenomenon occurred by a low power magnetron type ion source(ion magnetron). Experimental study of the characteristics and causes about this phenomenon is given.

1. Introduction

Ion magnetron generates a monochromatic and stable oscillation of high frequency($10^5 \sim 10^6$Hz) under the conditions of low power discharge($10^{-4} \sim 10^{-1}$W/cm^3), argon gas pressure of the 10^{-4} Torr level and the proper strength of a magnetic field coil current(described later). Beyond conditions of the monochromatic oscillation, oscillations have continuous spectra($0 \rightarrow 10^6$Hz). The relation between the monochromatic and continuous phenomena is alternative.

2. Ion Magnetron Device

A copper anode cylinder(59.2mm in diam. and 70mm in length) and a tantalum rod(0.5mm in diam.) are set with coaxial setting. The cathode rod emmits thermal electrons. Solenoidal coils(62mm in length) wrap the anode cylinder to generate roughly an axial magnetic fiels in the cylinder. The average flux density in the circular cross section at the middle of the cylinder is 12 gauss/ampere per unit magnetic field coil current. The decreasing ratio of the flux density is 0.15 gauss/ampere·mm toward the ends of the cylinder. Copper circular plates(diam.$>$60mm) are set 6mm apart from both ends of the cylinder. Through a hole of the plate an antenna(0.5mm in diam.) is inserted axially and let it go 3 mm in to the cylinder.

3. Experemental Results

Ion magnetron device is set in a vacuum chamber. Sample gas is introduced into the chamber.

A. Electron Cyclotron Oscillation: Without sample gas in the chamber the antenna feels electron cyclotron oscillation(frequency f_e). For example f_e=114MHz under the strength of the magnetic field coil current M.C.=2.9A. The theoretical and experimental equation of f_e(MHz) are f_e=33.6M.C. and f_e=39M.C. respectively.

B. Monochromatic Oscillation: When argon is introduced the antenna detects the frequency(f) of a stable monochromatic oscillation(Fig.1(a)). It is detected successively with varing M.C. under the gas pressure $P=1\times10^{-4}$ and 2×10^{-4}Torr, anode voltage U_2=200V and electron current intensity E.C.$\approx$5mA, when the empirical equation of f is given by f=0.047M.C.+f', where f'=0.24 and 0.07MHz for the respective argon pressures. Under $P=4\times10^{-4}$ Torr, the monochromatic oscillation is detected only at a point of M.C.. The point is given by M.C.=$0.1\sqrt[5]{U_2}$ with varing U_2 and the detected values of f are shown in Fig.2.

C. Continuous Spectrum: The ion magnetron generates oscillation of a continuous spectrum(Fig.1(b)) in almost any M.C. outside monochromatic conditions. The spectrum curve can be converted to the formula $N=\alpha \log f + \beta$, where N(dB) is output of the spectrum at f and α and β are constants. In many experimented cases values of α distribute near -40. For example in Fig.1(b) $\alpha = -39.5$. So the spectra in many cases give a simple formula $V_s \propto 1/f^2$, where $N=20\log V_s$.

4. Considerations

Sec.3.A. is described to let have the meaning, the test of the antenna. When gas sample is helium, the antenna detects frequencies about $\sqrt{10}f$.[1] This shows f(monochromatic) being of ions. Argon ion plasma frequency f_{pi} gives f_{pi} 4MHz for $P=4\times10^{-4}$ Torr and ion-neutral ratio=0.1% and $f \approx f_{pi}/10$. Argon ion cyclotron frequency f_{ci} gives $f_{ci} \approx 1$kHz for M.C.=2A and $f \approx 100 f_{ci}$. Argon ion reciprocating frequency f_{ri} gives $f_{ri} \approx 0.2$MHz for U_2= 200V and $f \approx f_{ri}$.[1] But in practice ion reciprocating motions are impossible in ion magnetron because of collisions of ions with each other and motions are presumed to be acoustic(resonance frequency f_{ri}).

5. Conclusion

The monochromatic oscillation may be an ion acoustic wave resonanced with a condition of f_{ri}. Outside the condition ion motions may fall to be scattered in a stable equilibrium state of the continuous spectrum as $V_s \propto 1/f^2$.

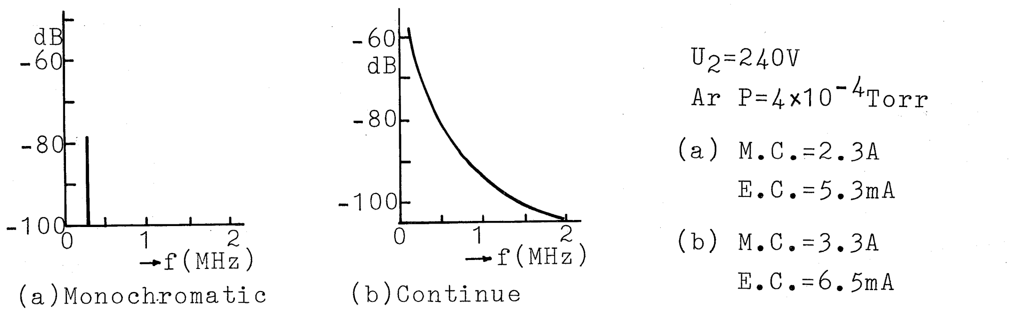

Fig.1 Spectra of oscillation phenomena in ion magnetron

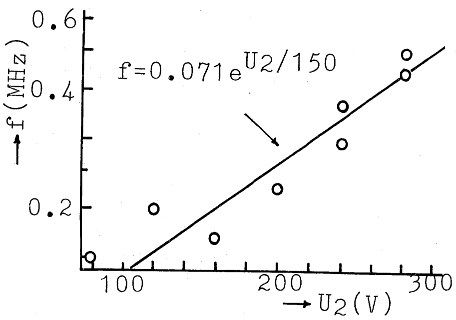

Fig.2 Relation between f(monochromatic) and anode voltage
E.C.≈5mA Ar $P=4\times10^{-4}$Torr

Reference

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