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Development of Magnetized Plasma Device Using Thermionic-Thermoelectronic Plasma Emitter

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Abstract

Development of a magnetic mirror device to explore basic plasma sciences relevant to fusion, space and astrophysical plasmas is presented. A large diameter (> 200 mm) plasma emitter, which utilizes thermionic- thermoelectronic emission from a mixture of LaB_6 (Lanthanum-hexaboride) and beta-eucryptite (lithium type aluminosylicate) powders, is employed as a plasma source because of its production ability of fully ionized plasma and controllability of plasma emission rate. The plasma emitter was installed and investigation of its characteristics is started. The employment of beta-eucryptite in plasma emitter is the first experimental test because such investigation of beta-eucryptite has previously been used only for Li^+ ion source. Our plan for magnetized plasma experiments and results of the plasma emitter investigation is presented.

Introduction

Plasma and Space Science Center at National Cheng Kung University in Taiwan has been developing a magnetic mirror device in order to conduct magnetized plasma experiments relevant to fusion and space plasma physics. Plasma turbulence, Alfven wave physics, electromagnetically induced transparency (EIT) and so on are set as research subjects. A magnetic mirror configuration is adopted for the experimental device because of its simplicity and versatility. This system consists of a vacuum chamber, vacuum pumping system, magnetic coils, plasma source, magnetron oscillator for plasma heating, and diagnostics/data acquisition system.

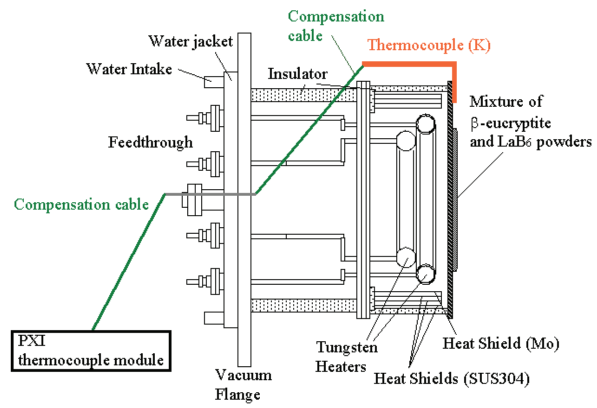

Fig. 1 Schematic of the plasma emitter

To perform high quality experiments it is critical to produce fully ionized plasma, which is difficult due to the presence of neutral particles. In order to solve this problem, we employ the plasma emitter [1]. This device can generate quiet, fully ionized plasma easily and does not need complicated arrangement for feeding alkali-metal vapor for the plasma production.

The plasma emitter was developed by Saeki, et al [1]. Their plasma emitter utilized a mixture of aluminosilicate (K_2O-Al_2O_3-$2SiO_2$) and barium oxide (BaO) as an ion emitter and electron emitter, respectively. Simultaneous emissions of potassium ions and electrons were synthesized in front of the emitter, resulting in a production of plasma. A plasma with density of 2×10^{14} cm^{-3} and temperature of 0.16 eV was obtained at an operating temperature of 1,300 K. A problem on employing potassium emitter is that potassium does not have available visible emission for observation of the plasmas. Although BaO has high emission property, activation is needed and exposure to air after the activation is not allowed.

The Plasma Emitter

Figure 1 shows a schematic of our plasma emitter. Mixture of powders of ion emission material and electron emission material covers a metal plate made of molybdenum with diameter of around 20 cm. Two tungsten heaters heat the metal plate up to 1,200 K with input power of ~1.5 kW. Temperature of the metal plate (the mixture) is measured by a K type thermocouple which leads to a thermocouple module (PXI SCC-TC02, National Instruments) through compensation cables and a feedthrough. The heater is surrounded by a molybdenum heat shield (innermost) and other three stainless steel heat shields (SUS304) to

Fig. 2 Molybdenum plate coated with mixture of beta-eucryptite and LaB_6 powders

prevent the radiation from being absorbed by other parts other than the emitter plate.

We employ lithium type beta-eucryptite of alkali alminosilicate (R_2O-$x$$Al_2O_3$-$y$$SiO_2$, R: alkari metal, x=1, y=2 for beta eucryptite) as ion emitter other than potassium type. Beta-eucryptite has been widely used for ion source of neutral Li beam plasma diagnostic systems in fusion plasma experiments. Ueda, et al. investigated Li+ emission property of the beta-eucryptite compound in pasty, liquid and glassy forms [2]. Emission rate of beta-eucryptite was found to be at ten times higher in glassy state than pasty one. Moreover lifetime of the Li emitter in high-current-extraction mode was much increased (two-three times longer than that of pasty form) when glassy sources were used.

Fig. 3 The installed plasma emitter in (top) vacuum and (bottom) energized state.

LaB_6 is adopted as an electron emitter due to the following reasons: 1) Activation is not necessary 2) It can be exposed to atmosphere. 3) It can be heated up to about 2,000 K which is quite higher than operation temperature of BaO (1,360 K). The peak emission rate of LaB_6 is at temperature range around 1,670-1,820 K. Experimental test of the plasma emitter has been initiated lately. A powder of beta-eucryptite was mixed well with a solution of LaB_6 in ethanol first. This mixture was attached on the molybdenum plate uniformly with thickness of ~0.2 mm as shown in Fig. 2. In this case, mass ratio of beta-eucryptite and LaB_6 powders was 2.2 g :2.2 g, radius of area coated with the mixture was roughly 15 cm. It was installed into the vacuum chamber and the heaters were energized with input power of ~1.5 kW by the DC power supplies. Photos of the installed plasma emitter are shown in Fig. 3 (top) and (bottom). Measurement of plasma density and temperature by Langmuir probes is now being prepared.

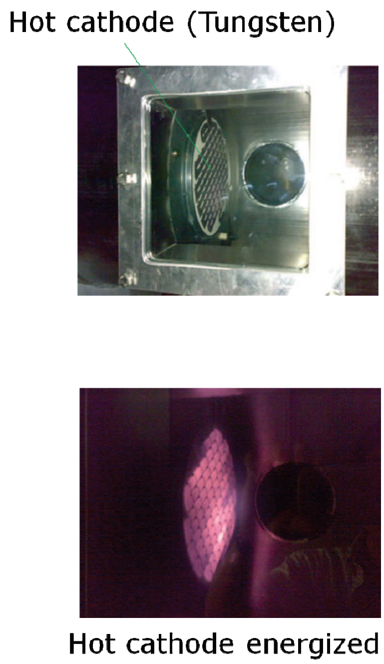

Fig. 4 Photos of the plasma emitter (top) and energized state (bottom) in the hot cathode mode.

Our plasma emitter has another operation mode called hot cathode mode than plasma emitter mode. The hot cathode mode generates thermal electrons and accelerates those to ionize introduced neutral particles by electron bombardment. Figure 4 shows photos of the plasma emitter (top) and its energized state (bottom) in the hot cathode mode.

Magnetic field coil system

The developed magnet system consists of five coils, three DC power supplies and a control system. Two of the five coils have 128 turns winding and operation of current of 500 A is possible (60,000 AT). The other three have 40 turns winding for 20,000 AT operation. All the coils are made of hollow conductor for water cooling. The three DC power supplies (IDRC, CDP-035-500, CDP-060-500) can energize maximum current of 500 A for these coils. Top of Fig. 5 shows a photo of the developed magnetic field coils (Takano Giken Ltd.). An example of measured and calculated magnetic mirror field profiles is shown in bottom of Fig. 5. Magnetic field strength in the order of 0.1 T was confirmed. The preprogrammed current control system of the magnets has been developing in order to provide magnetic field profile optimized to plasma discharges under various conditions.

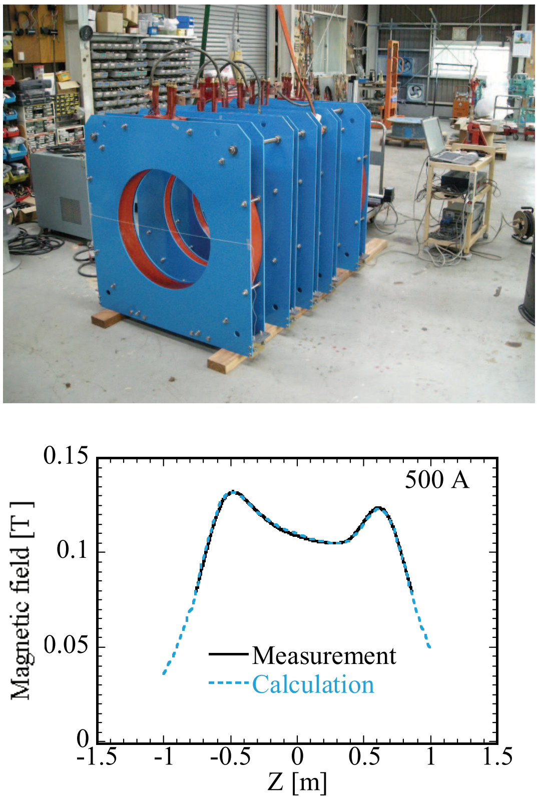

Fig. 5 A photo of the magnetic field coils (top) and measured and calculated profiles of magnetic field strength B_z (bottom).

References

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