§5. Direct Power Generation by High Heat Flux Divertor Plasmas

Ohno, N., Tomiyama, T., Kajita, S., Takagi, M. (Nagoya Univ.),
Masuzaki, S., Tokitani, M.

A thermionic energy converter (TEC), has been developed for a long time for application to nuclear thermionic power generator in spacecrafts and combustion heated thermionic power system, because TEC has good properties such as high conversion efficiency and simple configuration. A divertor plate in fusion devices receives huge heat load released from a core plasma. If the heat load onto the divertor plate can be converted to electricity by using TEC, the efficiency of fusion reactors could be improved.

Basic property of TEC has been investigated by using 2D Particle-In-Cell (PIC) simulation code. Figure 1 shows schematics of simulation model. We have investigated an influence of the magnetic field on power generation efficiency of TEC. The emitter and the collector are assumed to be made of tungsten with a work function of 4.5 eV and thoriated tungsten with a work function of 2.6 eV respectively. Surface temperature is assumed to be 2300 K. Magnetic field B_x along the axis of TEC is constant of 0.1 T and B_y parallel to the electrodes varies.

Figure 2 shows dependence of output current normalized by thermoelectron emission current from the emitter on the magnetic field strength B_y. As increasing B_y, the output current decreases gradually to be 0.4 at $B_y/B_x = 1$. This simulation result means that an increase of the incident angle of magnetic field line to the electrodes effectively expands the distance between the electrodes.

We made a TEC test module having tungsten and thoriated tungsten electrodes located with a inter-distance of $d = 0.06$ mm by using thin BN film as an insulator. We performed verification experiments of the TEC in a linear divertor plasma simulator NAGDIS-II. The emitter is heated by high density He plasma and the emitter temperature reaches above 2000 K. The plasma density can be controlled by varying the discharge current, and plasma density is almost proportional to the discharge current. The inset of Fig. 3 is a photograph showing the developed TEC module was irradiated by He plasma. Figure 3 shows the averaged output current of the TEC module as a function of the discharge current. The power output of TEC can be obtained above a discharge current of 30 A, and the power increases as proportional to the discharge current because the output voltage is constant determined by a difference of the work function of the two electrodes.

In summary, we have demonstrated power generation by the TEC in the divertor plasma enviroment. We are analyzing the experimental data to compare with the simulation result.

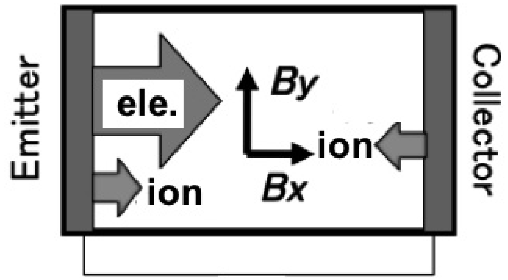

Fig. 1: Schematics of simulation model of TEC by 2D PIC code.

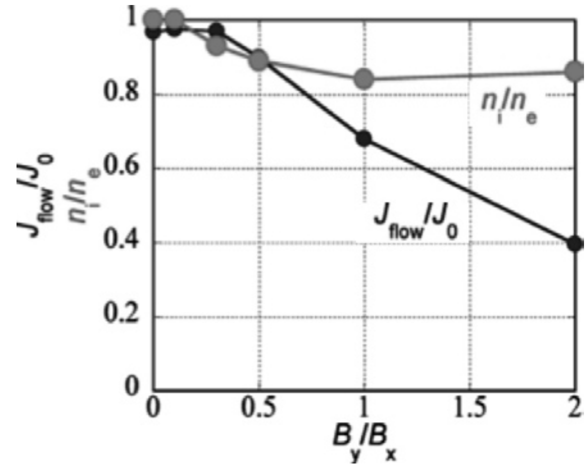

Fig. 2: Simulation result of the output current as a function of the magnetic field strength B_y. B_x is 0.1 T.

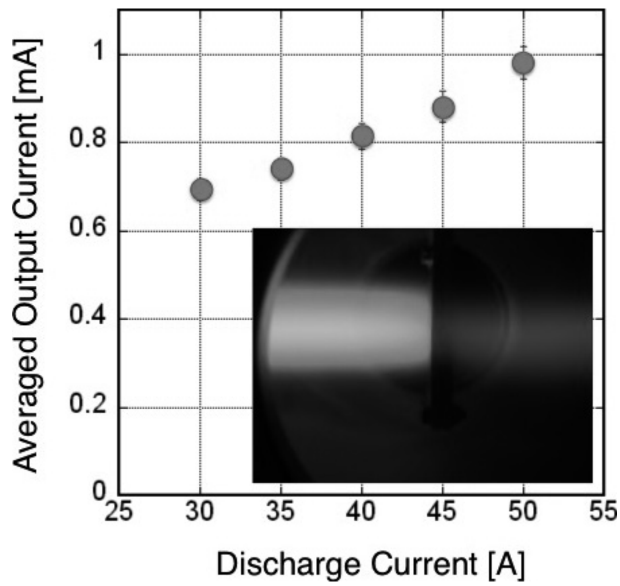

Fig. 3: Averaged output current as a function of the discharge current. The inset of the figure is the photograph showing the TEC module irradiated by a high density He plasma in the NAGDIS-II device.