半導体ヘテロ構造を用いた熱電子冷却効果
Thermionic Refrigeration Effect Based on Semiconductor Heterostructures

東大 生研[1]、LIMMS[2]、ナノ量子機構[3] 嚴惕非[1]、Aymen Yangui[1,2]、Marc Bescond[1,2]、長井奈緒美[1]、平川一彦[1,2,3]
IIS,[1] LIMMS,[2] and INQIE[3], Univ. of Tokyo Tifei Yan[1], Aymen Yangui[1,2], Marc Bescond[1,2], Naomi Nagai[1] and Kazuhiko Hirakawa[1,2,3]
E-mail: yantf@iis.u-tokyo.ac.jp

As the number of transistors on LSIs increases, a new technology to remove the heat energy dissipated from transistors and reduce the chip temperature is urgently required. We have fabricated a novel semiconductor heterostructure refrigeration device. This device utilizes both tunneling carrier injection and thermionic emission, as proposed by Chao et al. [1]. The potential profile of this device is shown in Fig. 1; a quantum well (QW) is sandwiched by two asymmetric potential barriers. In this structure, low energy electrons are injected from the emitter (left electrode) into the quantum well by resonant tunneling through the first thin and high barrier. These electrons absorb heat in the QW and are thermionically emitted over the thicker and low barrier. This thick barrier also works as a wall to reduce the heat backflow [1]. In this system, the low-energy carrier injection and subsequent thermionic emission give rise to refrigeration in the QW.

We used GaAs/AlGaAs heterostructures to fabricate the thermionic refrigeration structure, as shown in Fig. 1. Since it is very difficult to directly measure the temperature of the QW, we measured the photoluminescence (PL) of the samples to determine the electron temperature inside the structure. Figure 2 shows typical PL spectra measured at various bias voltages. By assuming the Maxwell-Boltzmann distribution for electrons, we deduced electron temperatures (T_e) for the QW and the electrode regions. Figure 3 shows the obtained T_e as a function of the bias voltage. As seen in the figure, T_e in the QW is reduced as much as 55 K, while T_e in the electrode is basically unchanged. This is a clear demonstration of the thermionic refrigeration effect in semiconductor heterostructures. IV characteristics of the samples is also shown in Fig 3.

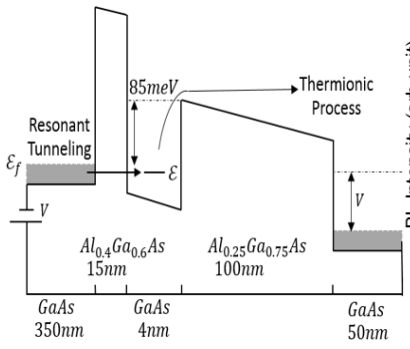

Fig. 1 Potential profile of a GaAs/AlGaAs thermionic refrigeration structure.

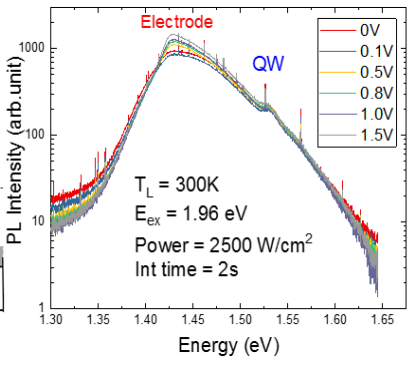

Fig. 2 PL spectra of a sample measured at 300 K at various bias voltages.

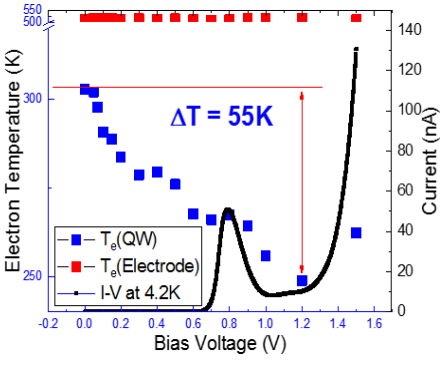

Fig. 3 Electron temperature in the quantum well and the electrode. I-V curve at 4.2K is also plotted.

Reference [1] K. A. Chao, M. Larsson, and A. G. Mal'shukov, Appl. Phys. Lett. **87**, 022103 (2005).