ヘテロ構造熱電子放出冷却構造中の電流ー電圧特性の温度依存性

Activation behavior of I-V characteristics in semiconductor thermionic cooling heterostructures

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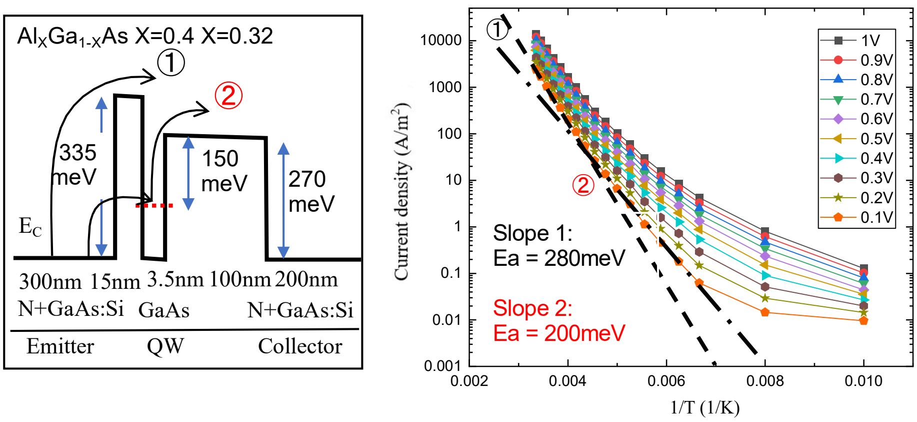
Managing rapid increase in thermal power densities associated with electronic miniaturization is a major technological challenge. Development of new efficient cooling technologies is therefore urgently required for future progress in electronics. Solid-state cooling devices can be one answer for their high efficiency and possibility to be integrated. To achieve such an efficient cooling, we design a semiconductor refrigeration structure with thermionic cooling effect. Cooling is achieved when cold electrons absorb energy to participate in the thermionic emission process.

We fabricate an asymmetric AlGaAs/GaAs double barrier heterostructure [1], as shown in Fig. 1(a). In the present heterostructure, we assume that the electron transport is due to resonant tunneling and subsequent thermionic emission. Cold electrons are first injected into the quantum well (QW) by resonant tunneling through thin barrier (emitter barrier) under a bias voltage. Then, electrons are thermalized in the QW and removed by thermionic emission over thick second barrier (collector barrier).

To clarify the transport mechanism, we have systematically measured *I-V* curves on the sample shown in Fig. 1(a). Figure 1(b) plots the temperature-dependence of the measure current at various bias voltages. As seen in the figure, the measured current shows an activation behavior. Furthermore, we notice that there are two slopes around 300 K and below 200 K. The activation energy determined at around 300 K is 280 meV, which is close to the height of the first emitter barrier (335 meV). The activation energy determined around 200 K is 200 meV, which is closer to the activation energy for the sequential thermionic process. Below 100 K, tunneling current becomes dominant. The present result indicates that, in order to achieve higher cooling efficiency, the structural parameters need to be optimized in such a way that the 2-step sequential current through the QW should be the main transport mechanism.



(a) (b)

Fig. 1 (a) Band structure of the sample, (b) Temperature-dependence of the current density

References [1] A. Yangui, M. Bescond, T. Yan, N. Nagai, K. Hirakawa, Nature Commun. (2019)10: 4504, (2019)