Development of a next-generation low-power transistors capable of operating at frequencies ranging from gigahertz to terahertz

Device

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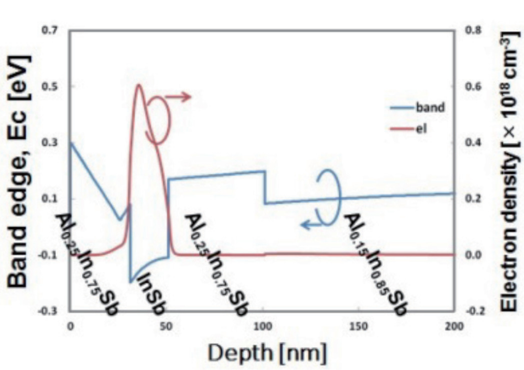
Purpose of Research

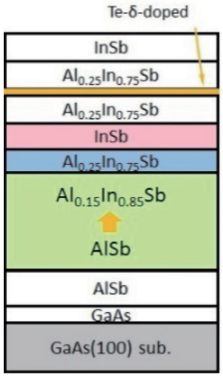
For technologies such as next-generation communications, unexplored sensing technologies, and ultimate computing to be achieved, new high-frequency low-power transistors are required. To develop such devices, we are conducting research into transistors using Sb-based compound semiconductors that exhibit high electron mobility.

Summary of Research

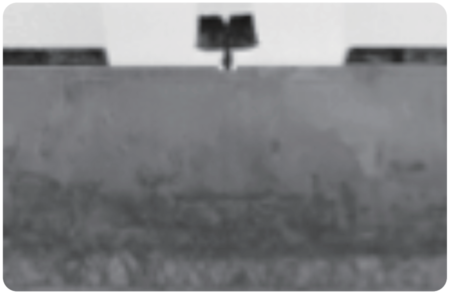
To develop a high electron mobility transistor (HEMT) that can operate at frequencies ranging from the millimeter-wave band to the terahertz wave band (30 GHz–1 THz) using Sb-based compound semiconductors, we carried out the design and analysis of the device by means of a Monte Carlo simulation of HEMT using an InSb-based material, fabricated and evaluated the HEMT epitaxy structure using a molecular beam epitaxy (MBE) apparatus, and then fabricated and evaluated the device.



Simulation results for the band structure and electron density distribution of the strain-controlled InSb HEMT



Layer structure of an InSb quantum well channel for which the electron mobility has been increased by strain control



Cross-sectional TEM image of the prototype strain-controlled InSb HEMT (gate electrode length: 80 nm)

Points

- **High-frequency operation (30 GHz–1 THz)**
- **Low-power consumption**

Comparison with Conventional or Competitive Technologies

InSb exhibits electron mobility that is more than 50 times higher than that of Si, and it is attracting attention as the third-generation electronic material following GaAs- and InAs-based materials. It is possible to produce a material that will deliver a world-leading performance that is superior to that of GaAs- and InAs-based materials by applying the following: a device structure design that makes full use of band engineering and strain engineering; thin film growth at the atomic layer level that realizes the design; and ultrafine processing at the nanometer level.

Expected Applications

The terahertz range of the invisible light and electromagnetic spectrum is regarded as being a suitable bandwidth for unexplored sensing technologies, next-generation communications, ultimate computing, and the like. It is expected to be applied in a variety of fields, including manufacturing, telecommunications, medicine, biotechnology, agriculture, and security. InSb-based HEMT can make a significant contribution to the realization of applications such as an ultimate-performance low-power transistor that is capable of operating in the terahertz range.

Challenges in Implementation

We aim to stably achieve a high-level transistor performance in the terahertz range and further pursue the formation of an IC.

What We Expect from Companies

The InSb-based material is attracting attention not only as a high-speed high-frequency transistor, but also as a channel material for LEDs, light detectors, and the like in the terahertz to far-infrared range. We are searching for companies and research institutions that can work together on developing practical uses for this material.

Future Developments

2015: Test production of an ultimate-performance InSb-based transistor that operates in the terahertz range
2016: Evaluation of properties and improvements to performance
2016: Test production of a low-noise IC

- Intellectual Property: Japanese Unexamined Patent Application Publication No. 2014-045024 "Production Method for Semiconductor Devices"
- Awards: Distinguished Services Award for Electronics Society Initiatives received from the Institute of Electronics, Information and Communication Engineers (2011)