【Grant-in-Aid for Scientific Research (S)】

Science and Engineering (Interdisciplinary Science and Engineering)

Title of Project : Establishment of Fundamental Engineering of Sn-related Group-IV Semiconductor Materials for Multi-Functional and Low-Power Electronics

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Research Project Number : 26220605 Researcher Number : 70158947
Research Area : Thin film/surface interface science
Keyword : semiconductor, crystal engineering, surface/interface, germanium tin, energy band

【Purpose and Background of the Research】

Low-power consumption, high speed, and multi-functional electronic devices are required for Si ultra large scale integrated circuits to extend their applications. In this project, we develop the crystal growth technology and electronic property engineering of group-IV semiconductor materials including GeSn and GeSiSn, *etc* for tunnel field effect transistor (TFET) and optoelectronic devices. We challenge to clarify the energy band, strain, and defect structures and electronic and optoelectronic properties of GeSn and GeSiSn thin films. We also establish the engineering technology of Sn-related group-IV semiconductors and develop the process technology for innovation of Si nanoelectronics.

【Research Methods】

We promote following research themes of Sn-related group-IV semiconductor materials.
(1) We investigate the crystal growth of GeSn and GeSiSn layers by using molecular beam epitaxy *etc.* for high quality thin films with a high Sn content and controlled carrier property.
(2) We develop the technology of controlling defects and strain structure in GeSn, GeSiSn, and GeSnC *etc.* for electronic applications. We investigate the local strain and defect structures. We also investigate the influence of fabrication processes and device structures on the nano-scale properties at metal/semiconductor (MS) and metal/oxide/semiconductor (MOS) interfaces.
(3) We examine the formation of high Sn content GeSn layer being a direct transition semiconductor. We investigate the carrier, optical absorption, and luminescence properties of GeSn and GeSiSn to understand and control those energy band structures.

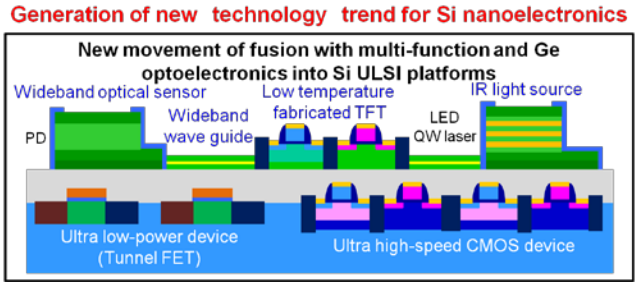

Figure 1 Concept of multi-functional devices with Sn-related group-IV semiconductors.

(4) We develop the technology engineering doping and MS and MOS interfaces for GeSn materials. We examine the formation of metal electrode and high permittivity metal oxide thin films on GeSn and GeSiSn, and investigate the interfacial reactions and their electrical properties.
(5) We develop the process technology for the device fabrication of TFET and optoelectronic devices, and investigate the device properties.

【Expected Research Achievements and Scientific Significance】

Achievements of this project promise that the fundamental engineering technology of GeSn and GeSiSn will be established for low-power, high speed, and multi functional devices. The new technology of group-IV semiconductor materials will be fused into Si CMOS technology. In addition, new nanoelectronics technology will be established for TFET and direct semiconductor group-IV semiconductor optoelectronic devices, and those will contribute to the evolution for electronics industries in Japan. From the view point of academic science, new and interesting materials science will be advanced with the generation of direct semiconductor and energy band engineering of group-IV semiconductors.

【Publications Relevant to the Project】

• S. Zaima, "Technology Evolution for Silicon Nanoelectronics: Postscaling Technology", Jpn. J. Appl. Phys. **52**, 030001 (12 pages) (2013).
• O. Nakatsuka, Y. Shimura, W. Takeuchi, N. Taoka, and S. Zaima, "Development of epitaxial growth technology for $Ge_{1-x}Sn_x$ alloy and study of its properties for Ge nanoelectronics", Solid-State Electron. **83**, pp. 82-86 (2013).

【Term of Project】 FY2014-2018

【Budget Allocation】 138,600 Thousand Yen

【Homepage Address and Other Contact Information】

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