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

Research on SiC Extreme-Environment Electronics for Exploring Human's New Frontiers

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Project Information	Project Number : 24H00035 Project Period (FY) : 2024-2028 Keywords : Silicon Carbide, CMOS Integrated Circuits, High temperature, High radiation

Purpose and Background of the Research

●Outline of the Research

From the twentieth century, the boundaries of human activities are expanding with geographical frontiers like space and deep underground, and scientific frontiers like massive accelerator and nuclear fusion reactors. Silicon semiconductor electronics strongly have been providing support for cultivating these frontiers. However, by the frontier expanding, high-temperature operable radiation-hardened electronics have been requested. For that, we proceed with research and development on silicon carbide (SiC) extreme-environment electronics.

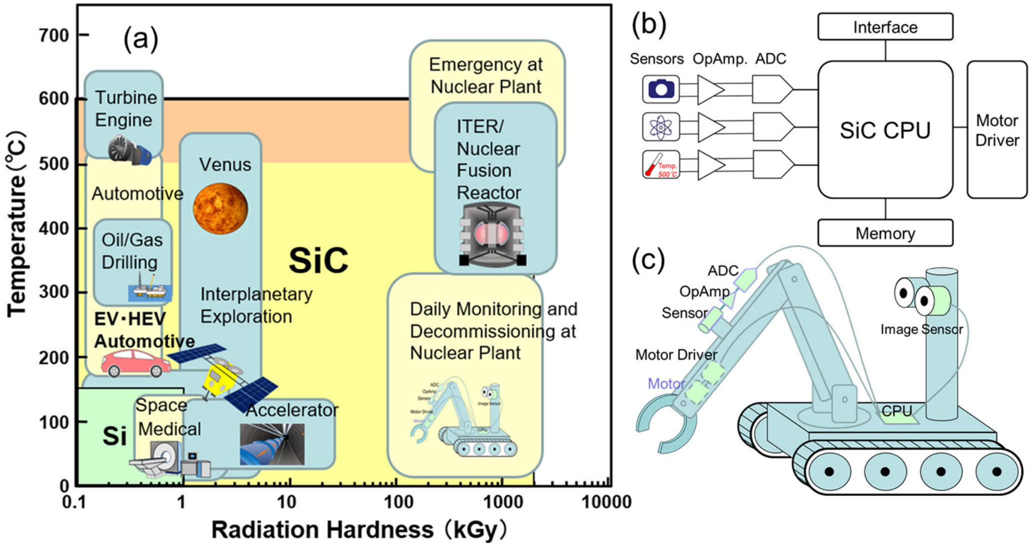

Figure 1. (a) Applications of our SiC extreme environment electronics, (b) the circuits block diagram, and (c) schematic for a robot with corresponding electronics.

● Our New Frontiers and SiC Extreme-Environment Electronics

New frontiers for our human race are expanding to space, deep underground etc. The features of these frontiers are characterized by harsh environments with high-temperature, high-radiation. The electronics operable such harsh environment have been required. These electronics have been also required for decommissioning of nuclear power plants, oil/gas-drilling, space and planetary exploration, industries such as automobile and turbine engine, and medical applications. Our objective is to realize the SiC Extreme-Environment Electronics, which consist of SiC CPU, sensor systems, motor drivers, etc shown in Fig.1.

●SiC Integrated Circuits

Silicon carbide (SiC) semiconductor is compound of silicon and carbon with the ratio of 1:1, with a wide-bandgap of 3.26 eV.
The SiC semiconductor, which begun to be used as high-performance power devices for EVs and trains, has also a great potential for the extreme environment application owing to its wide bandgap. We are developing SiC integrated circuits for such the extreme environment applications.
On the application as the power semiconductor devices, N-type transistors (nMOSFETs) are mainly used. On the other hand, for integrated circuits, both of N-type and P-type transistors are expected to be used as CMOS circuits. In this research, we will investigate physics on the SiC pMOSFETs. The reliabilities of metal wires and contacts are also critical factor for high-temperature long-time operation. We will investigate the material science for obtaining high-temperature reliability.

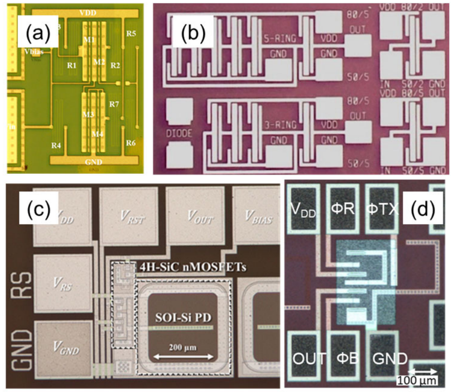

Figure 2. SiC Integrated Circuits developed by our research team: (a) SiC amplifier circuit, (b) SiC CMOS circuits, (c) , (d) SiC Active Pixel Sensors.

Expected Research Achievements

●Device and Process Physics for enhancing SiC CMOS performance

SiC CMOS device technologies including threshold voltage control of SiC pMOSFETs.

●Material Science for Obtaining High-Temperature Reliability

Research on metal wires and silicide ohmic contacts for high-temperature operation.

●Radiation-Hardened Device Structures

Research on radiation-hardened CMOS structures and its process technologies.

●SiC CMOS Integrated Cirsuits

Design and fabrication of the SiC CMOS integrated circuits, and device modeling.

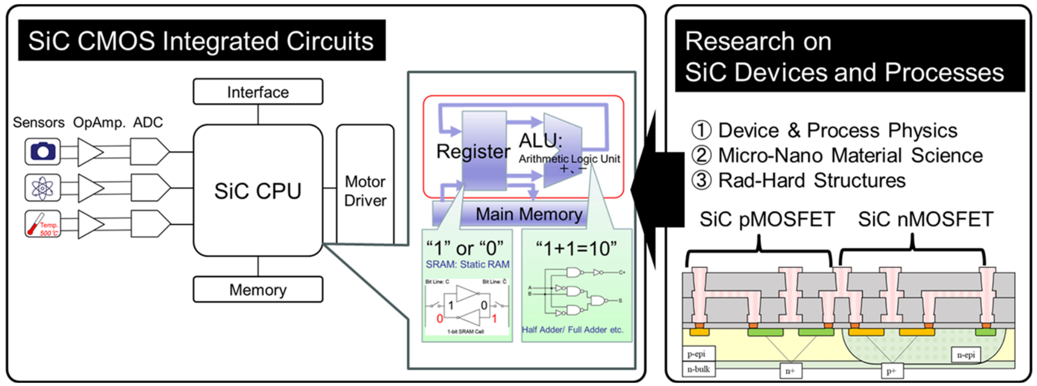

Figure 3. Research on SiC CMOS integrated circuits and SiC Devices and processes.

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