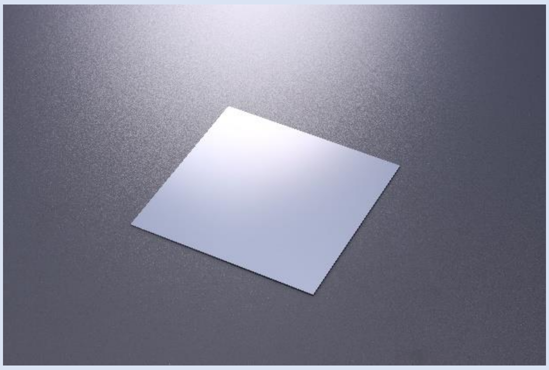
東洋アルミニウム技報
Toyal Technical Report
New Business | July 2025



SiGe/Si Wafer

Toyo Aluminium K.K.
Advanced Materials Research Unit
Functional Electronic Materials
Development Team
Ryo Nakao

【1． Introduction】

Silicon–germanium(SiGe)–based semiconductor materials are among the most promising candidates for next-generation electronic and optoelectronic devices owing to their superior carrier mobility, tunable bandgap, and low power consumption. However, because Si and Ge have melting points of 1414 °C and 938 °C, respectively—a difference of approximately 476 °C—and form a complete solid solution, it is extremely challenging to fabricate high–bulk-quality SiGe single crystals with well-controlled Ge composition and without polycrystalline inclusions.

Conventional epitaxial techniques such as chemical vapor deposition (CVD) and molecular beam epitaxy (MBE) have been widely employed to form SiGe single-crystal layers. Nevertheless, both methods require high-vacuum conditions, long processing times, and expensive large-scale equipment, which significantly limit their industrial scalability. Liquid phase epitaxy (LPE) offers the advantage of forming SiGe layers 20–30 μm thick with relatively low defect densities. However, traditional LPE processes necessitate large furnaces and specialized apparatus for bulk or thick-layer SiGe crystal growth.

To overcome these limitations, we have focused on Al-induced recrystallization (AIR), an LPE-related technique that enables the formation of SiGe layers at comparatively low temperatures. This approach allows Si and Ge to melt and interdiffuse below 1000 °C, thereby providing a simple, energy-efficient, and rapid route to achieve epitaxial-quality SiGe layers[1)].

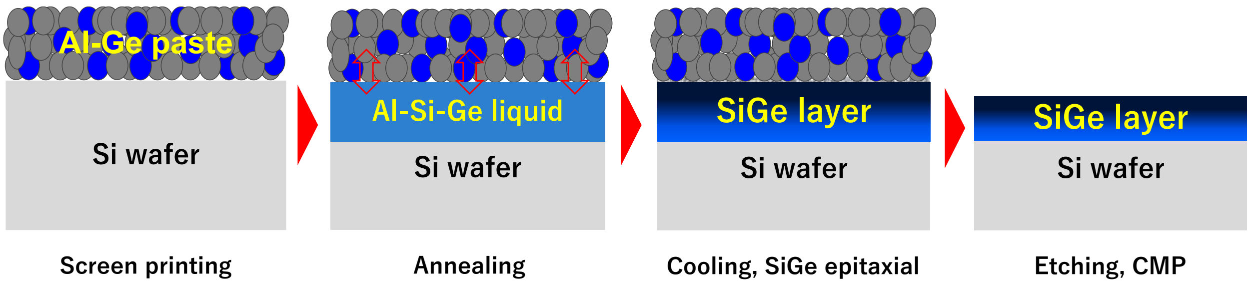


Fig.1 Production Process of SiGe/Si wafer

【2． Features of the Proposed Method】

To establish a practical and scalable process for SiGe single-crystal growth, we developed the SiGe Liquid–Quick Epitaxy (LQE) method. This technique combines screen printing of an Al–Ge paste onto a Si substrate followed by controlled thermal treatment. The overall fabrication sequence is illustrated schematically in Figure 1.

Unlike CVD and MBE, the LQE process enables the formation of thick SiGe layers—on the order of tens of micrometers—without the need for vacuum equipment. Because the process relies solely on screen printing and heating, it offers excellent scalability for large-area wafer production. Furthermore, both the thickness of the SiGe layer and its Si/Ge ratio can be precisely adjusted by modifying the Al/Ge composition in the printed paste[2].

① Cross-Sectional Morphology

Figure 2 shows the SEM cross-sectional image of a SiGe/Si wafer fabricated on a 6-inch Si (111) substrate. A continuous SiGe layer approximately 30 μm thick is clearly observed on the Si substrate, demonstrating successful layer formation.

The corresponding elemental distribution obtained by SEM–EDX (Figure 3) indicates that the Ge concentration in the SiGe layer is approximately 10 at.%, confirming effective alloying and interdiffusion.

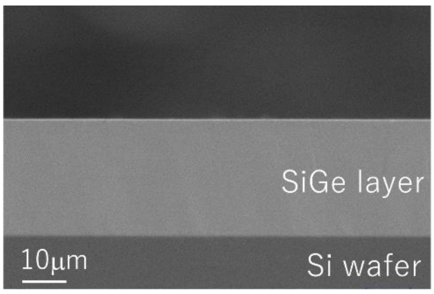


Fig.2 SEM cross-section of SiGe/Si wafer.

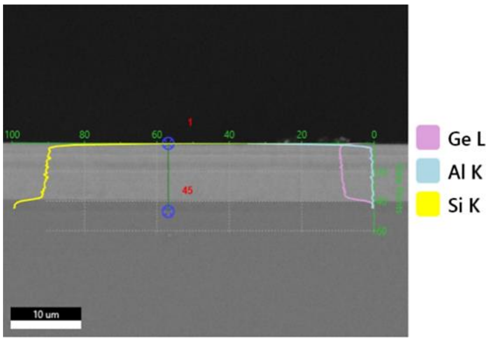


Fig.3 Elemental profile across the SiGe/Si cross-section measured by SEM–EDX.

② Surface Morphology and Roughness

The surface topography of the SiGe/Si wafer after chemical–mechanical polishing (CMP) was characterized using a laser microscope (Figure 4). The average surface roughness (Sa) was measured to be 2.86 nm, demonstrating that the SiGe layer exhibits excellent smoothness and surface uniformity suitable for subsequent device processing.

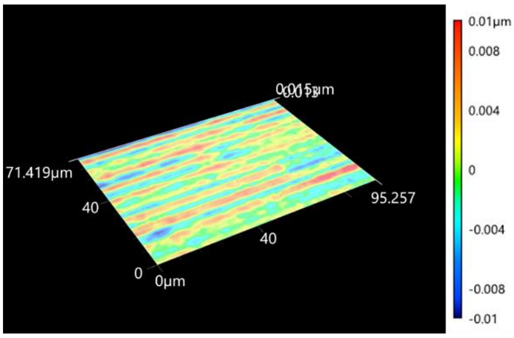


Fig.4 Surface roughness of SiGe/Si wafer after CMP measured by laser microscopy.

③ Crystallinity and Strain Analysis

The crystalline quality and strain state of the SiGe layer were examined by X-ray diffraction reciprocal space mapping (XRD–RSM), as shown in Figure 5. Distinct diffraction peaks corresponding to the Si substrate and the SiGe layer confirm epitaxial growth. The relative shift of the SiGe peak indicates partial strain relaxation, reflecting high crystalline quality and lattice coherence within the epitaxial layer.

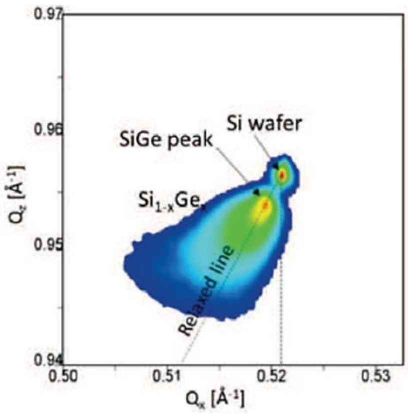


Fig 5. XRD–RSM characterization of SiGe/Si wafer.

【３． Future Development Prospects】

Our previous studies have demonstrated that SiGe layers containing up to 80 at.% Ge can be achieved on small-area substrates using the LQE approach. Future work will focus on extending this process to large-area Si wafers while maintaining compositional uniformity and crystalline integrity. Ultimately, we aim to develop high-Ge-content SiGe/Si heterostructures suitable for integration into next-generation semiconductor devices, including tandem solar cells, high-speed transistors, and other low-power electronic applications[3].

【４． Refarences】

1)Shota Suzuki and Marwan Dhamrin, Mnufacturing & Technology, Vol.74 No.3(2022), 51-54

2)Masahiro Nakahara, Moeko Matsubara, Shota Suzuki and Marwan Dhamrin, Abstract of the 136th The Japan Light Metal Institute Annual Meeting (2019), 301-302.

3)Shota Suzuki, Moeko Matsubara, Hideaki Minamiyama, Marwan Dhamrin and Yukiharu Uraoka, Effect of annealing ambient on SiGe layer formation using Al-Ge paste for III-V solar cell application, Japanese Journal of Applied Physics, 62 SK1041 (2023).