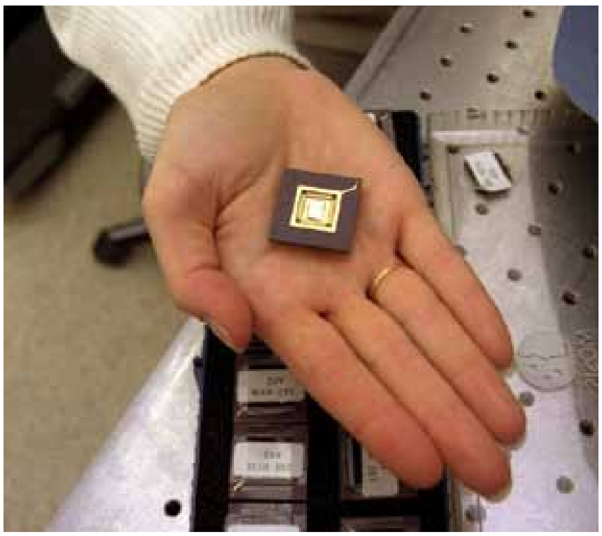
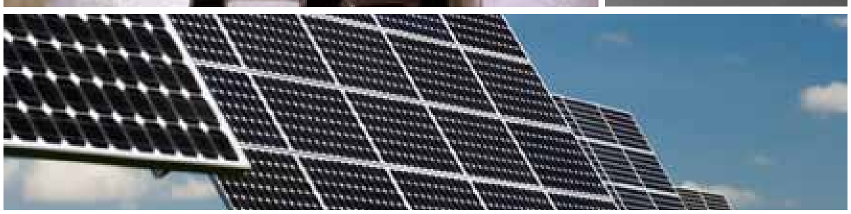
National Aeronautics and Space Administration

technology opportunity

Rhombohedral Super Hetero Epitaxy of Silicon-Germanium (SiGe)

Exhibits charge mobility more than twice that of silicon





NASA's Langley Research Center invites companies to license a fabrication method for the first rhombohedrally grown SiGe semiconductor alloy structure that will enable the development of ultra-fast chipsets exhibiting charge mobility of more than 3,000 cm^2/Vs—well beyond the state of the art for semiconductor chips. The rhombohedral-trigonal super hetero epitaxy technology produces unprecedented semiconductor structures with much better performance. It also uses a conventional silicon oxide insulator, enabling wafer-scale mass production. The technology includes growth of rhombohedral-trigonal hybrid crystal structures and advanced X-ray diffraction characterization methods for defect control.

Benefits

- **Faster:** Has over twice the charge mobility of single-crystal, silicon-based chips
- **Better performance:** Improves performance with new lattice-matched conditions
- **Superior quality:** Produces superior quality, graded, indexed SiGe layers with fewer defects
- **Low implementation cost:** Uses existing silicon fabrication facilities for production
- **Mass production:** Enables wafer-scale mass production through compatibility with conventional SiO^2 insulators
- **Versatile:** Allows varying material thicknesses including Si/Ge/SiGe quantum wells

Applications

- High electron mobility transistors and hetero-bipolar transistors used for high-speed computing and wireless communications
- Photovoltaic solar cells
- Thermoelectric systems
- Radiation detectors
- Optoelectronic devices with quantum wells

Patents

Two U.S. patents have been issued for this technology (Nos. 7,514,726 and 7,341,883). Four additional patent applications have been filed.

Licensing and Partnering Opportunities

This technology is part of NASA's Innovative Partnerships Program, which seeks to transfer technology into and out of NASA to benefit the space program and U.S. industry. NASA invites companies to consider licensing this Rhombohedrally Lattice-Matched Silicon-Germanium (SiGe) (LAR-16868-1, LAR-16872-1, LAR-17185-1, LAR-17405-1 and LAR-17553-1) for commercial applications.

Technology Details

Until now, no alternative materials have offered high charge mobility with compatible insulator materials to replace the widely used silicon, so chipset speed essentially has been limited by the feature size of the chip. Development of faster chipsets has been cost prohibitive without new semiconductor materials that exhibit high carrier mobility as an intrinsic property because new manufacturing fabs, capable of reaching nanometer scales, are necessary for reducing feature size.

How It Works

The traditional alloys (e.g., carbon, silicon, germanium, and tin) cannot be simply deposited on commonly used substrates (e.g., silicon) because the alloys' crystal lattice constants differ from the substrate structure. Lattice mismatches, which occur when a SiGe alloy is deposited onto silicon, lead to defects including dislocations, cracks, and delamination. Traditional epitaxy technology uses two distinctive mathematical frames to design new alloys, the cubic crystal unit cell and the hexagonal crystal unit cell.

The new epitaxy technique aligns a rhombohedral transformation of SiGe cubic crystals with trigonal crystals such as a sapphire substrate. Because rhombohedral crystal structures are mathematically equivalent to trigonal crystal structures, cubic crystals can be epitaxially grown on trigonal crystals in rhombohedral alignment and vice versa. With this new rhombohedral-trigonal alignment, unprecedented lattice-matching conditions can be found as well. Such conditions reduce defects (e.g., dislocations) and result in improved semiconductor devices. Although trials by others failed because of the lack of a non-destructive evaluation method, this method stabilizes rhombohedral epitaxial growth of SiGe alloys on trigonal sapphire with a new X-ray diffraction characterization.

Conventional silicon-based chipsets have achieved clock frequencies of approximately 144 gigahertz by decreasing micro-circuit line resolution to 45 nm. However, further improvement has been limited because of the material properties. This rhombohedral, lattice-matched, single-crystal SiGe with quantum well structures can increase the charge mobility of SiGe beyond 3,000 cm^2/Vs, which at the same resolution offers clocked speeds of up to 308 gigahertz.

Why It Is Better

NASA's rhombohedrally aligned SiGe is the first of its kind. Ultra-fast semiconductor chipmakers have long awaited the increases in speed possible with the SiGe compound—well beyond that of silicon-based chip technology. Because this technology allows Si/Ge/SiGe quantum wells with faster electron and hole mobilities than bulk single-crystal silicon, it will enable the development of ultra-fast chipsets for numerous applications.

Although several high-charge mobility compound semiconductor materials (e.g., zinc blends and wurzites) are available, they are costly and do not allow the proper insulator materials to make mass production possible. The rhombohedrally aligned SiGe enables narrow gate length in wafer-scale mass production because a conventional silicon oxide insulator can be used. In addition, Si/Ge/SiGe quantum well structures and new lattice-matching conditions on various trigonal substrates are to be explored and utilized further.

For More Information

If you are interested in more information or want to pursue transfer of this technology please contact:

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