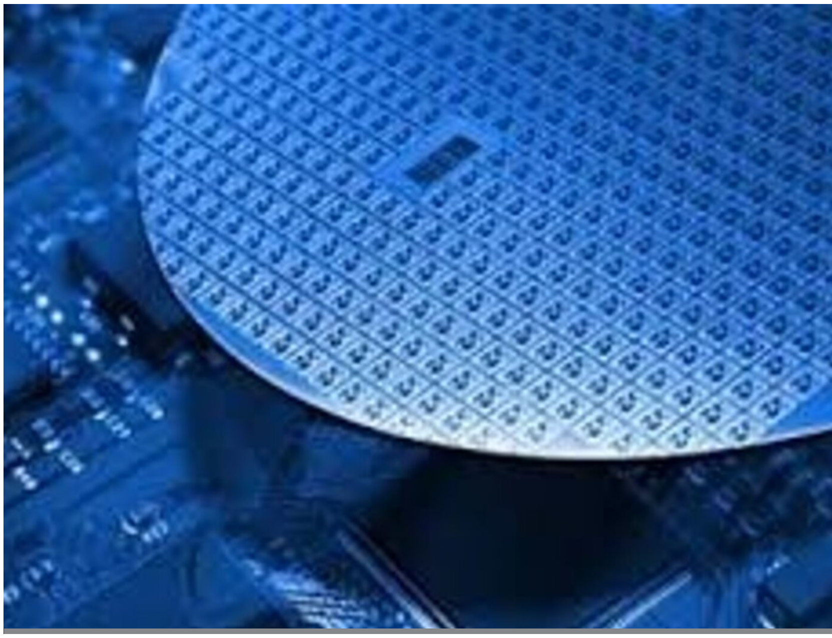


National Aeronautics and Space Administration

TECHNOLOGY SOLUTION

Materials and Coatings

Epitaxy of SiGe and Other Compound Semiconductors

Technologies for growing compound semiconductors on various trigonal and hexagonal structured substrates such as sapphire substrate

NASA engineers have developed a suite of technologies that enable super-hetero-epitaxial growth of silicon germanium (SiGe) and other compound semiconductors on sapphire and other trigonal and hexagonal structure substrate wafer materials. A focus for NASA has been on the development of methods to make SiGe crystal materials for the manufacture of advanced semiconductor devices for aerospace applications. This suite of technologies, however, is even more broadly applicable to making various semiconductors of Group IV, III-V, and II-VI compounds. The technologies include super-hetero-epitaxial growth using carefully engineered crystal structures/orientations combined with sputtering and control substrate heating. Also included are novel x-ray diffraction methods for detecting and mapping crystal twin defects that can arise during super-hetero-epitaxial growth. The specific case of growing highly twinned SiGe crystal layer structures for use in making high temperature thermoelectric devices is enabled as well.

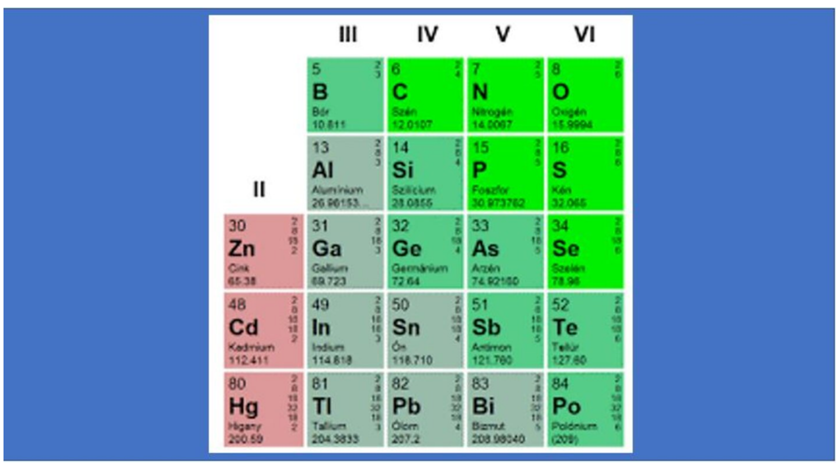
BENEFITS

- Widely enabling: Suite of patented technologies enabling the manufacture of high-quality compound semiconductors on a variety of trigonal and hexagonal structured substrates.
- High-quality, defect-free: SiGe crystals grown on sapphire substrates, as a particular focus of these innovations, can be used to manufacture a number of advanced high performance semiconductor devices.
- Innovative processing: Physical vapor deposition (sputtering) of high-quality crystal structures is provided by selected crystal structure alignment coupled with energetic atomic transport and surface crystal arrangement (via high-temperature molten sputtering targets and controlled substrate heating).
- Innovative characterization: X-ray diffraction methods for detecting and mapping crystal twin defects in the as-grown semiconductor crystal material.
- New applications: Novel high temperature thermoelectric devices based on SiGe with highly twinned lattice structures, which reduce thermal conductivity without compromising electrical conductivity.

THE TECHNOLOGY

Several of the patented methods included in this suite of technologies enable super-hetero-epitaxy of rhombohedral/cubic compound semiconductors on specially oriented trigonal (e.g. sapphire) or hexagonal (e.g. quartz) crystal wafer substrates. This includes alignment of the growth crystal lattice with the underlying substrate lattice to minimize misfit strain-induced dislocation defects in the growing crystal. Thus thicker, defect-free crystal layers can be made. Rhombohedral/Cubic crystal twin defects which is 60 degree rotated on [111] orientation in a rhombohedral/cubic SiGe layer structure can be reduced to well less than 1% by volume, essentially providing a defect-free semiconductor material. Alternately, engineered lattice structures with a high degree of twinning can provide SiGe with improved thermoelectric properties due to the phonon scattering that inhibits thermal conduction without compromising electrical conductivity. Additional patented technologies in this suite provide for physical vapor deposition (PVD) growth methods utilizing molten sputtering targets and thermal control of heated substrates, including electron beam heating, in order to give the atoms in the sputtered vapor or on the substrate surface the energy needed for the desired crystal growth.

The remaining patented technologies enable x-ray diffraction methods for detecting and mapping crystal twin defects across the entire as-grown semiconductor layer. These defects are critical to the performance of any semiconductor device manufactured from such compound semiconductor materials.



This suite of technologies can be used to develop and manufacture a range of advanced semiconductor crystal alloys based on Group IV, III-V, and II-VI compounds.

APPLICATIONS

The technology has several potential applications:

- This suite of technologies can be used to manufacture a range of novel, high-performance semiconductor devices like bipolar and high-mobility transistors. Additionally, novel photovoltaic, LED, phase shifter, power IC chips, RGB LEDs and thermoelectrics devices can be developed and manufactured using these methods. These high-performance devices can be used in various aerospace, industrial and consumer applications, including for extreme environments.

PUBLICATIONS

Patent No: 11,299,820; 10,858,754; 7,558,371; 7,906,358; 8,044,294; 7,769,135; 8,257,491; 11,885,040

More Information

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