National Aeronautics and Space Administration

TECHNOLOGY SOLUTION

Electrical and Electronics

Single Crystal Semiconductor Silicon-Germanium (SiGe)

A suite of methods for efficient manufacturing of SiGe and other semiconductors

With 4x faster carrier mobility and less energy loss than single crystal silicone, single crystal SiGe offers increased processing power and decreased size, and power demands for a unit of the same size. These capabilities exceed current market options for semiconductors.

In solar cell applications, SiGe offers new design features that improves its efficiency to 30~40% and the operational life to ~80 years. SiGe is also a comparatively more abundant resource, lower cost and non-toxic, unlike standard solar materials.

With SiGe production technologies suite consistent quality production and lowered production costs and waste can be ensured while maintaining expeditious production. Once production is operational, the processes are expected to be equivalent in manufacturing cost to poly-crystal SiGe.

BENEFITS

- Speed and cost: MTS (Molten Target Sputtering) lowers process temperature 300 Celsius
- Faster heating using a removable Thermally Absorption Coating (TAC)
- Higher yields: Reduced thermal gradient increases semiconductor uniformity
- Methods available to further thick-film growth of semiconductor materials
- Smoother, denser, more crack resistant Single crystal semiconductor growth
- Epitaxial layer with high carrier mobility

THE TECHNOLOGY

Single Crystal SiGe semiconductors are viable via numerous advances patented by NASA. This includes the addition of a 1-2mm ring groove in the magnetron magnets which increases sputtering energy at 500C vs 800C, enabling thicker, faster deposition with better surface finish and consistent quality without heat soaking. The lack of thermal gradient removes inconsistencies in the product. SiGe can also utilize the CMOS manufacturing technique for additional cost savings and waste reduction.

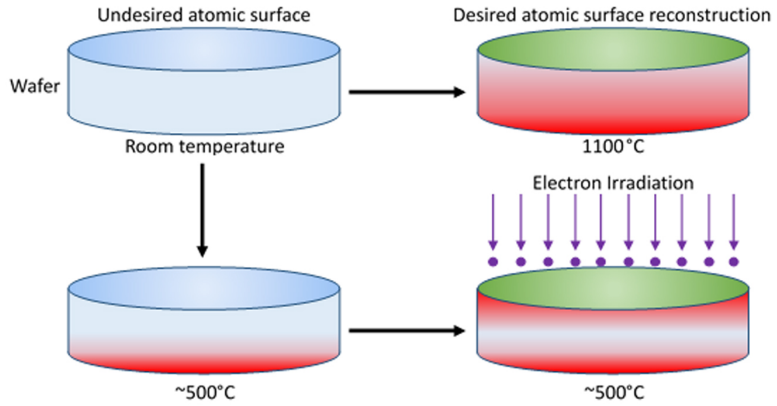
Further decreases to time investment for single crystal SiGe is made possible via reduced thermal load and soak temperatures, growing SiGe semiconductors on, conveniently, less expensive sapphire substrates. Crystal lattice matched growing methods to the sapphire substrate ensure defect-free SiGe production without interfacial dislocations.

A graded indexed SiGe layer can be added to wafers grown in this lattice matched method, permitting thicker semiconductor growth without abrupt changes in strain build-up, carrier potential barrier, index of refraction change and bandgap at the interface. These advances provide improved semiconductor performance and quality with fewer defects in fabrication. The crystal alignment enables X-Ray diffraction identification of any defect location and density.

It is also possible to also grow a Gallium Nitride or Indium Gallium Nitride layer on the opposite side of the Sapphire wafer, useful for solar capable LED display.

A type II band-gap alignment of SiGe would result in highly efficient solar cells – attaining 30% to 40% energy conversion efficiency.

In addition to SiGe, the patented technology also covers these methodologies on tin-based or carbon-based semiconductors.



Processes comparing existing and patented process for developing crystal aligned semiconductor wafers Image Credit: NASA

APPLICATIONS

The technology has several potential applications:

- Solar cells
- Computer chips (CMOS transistors)
- Light emitting diodes (LEDs)
- Thermo-electric generators
- Microelectronics
- Next generation semiconductor devices
- Transparent, conductive oxide films with high transmittance (at IR and visible region), wide band-gap, and low resistivity

PUBLICATIONS

Patent No: 10,096,472; 7,341,883; 7,514,726

Patent Pending

technology.nasa.gov

NASA's Technology Transfer Program pursues the widest possible applications of agency technology to benefit US citizens. Through partnerships and licensing agreements with industry, the program ensures that NASA's investments in pioneering research find secondary uses that benefit the economy, create jobs, and improve quality of life.

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