Rhombohedral Super Hetero Epitaxy of Cubic SiGe on Trigonal c-plane Sapphire

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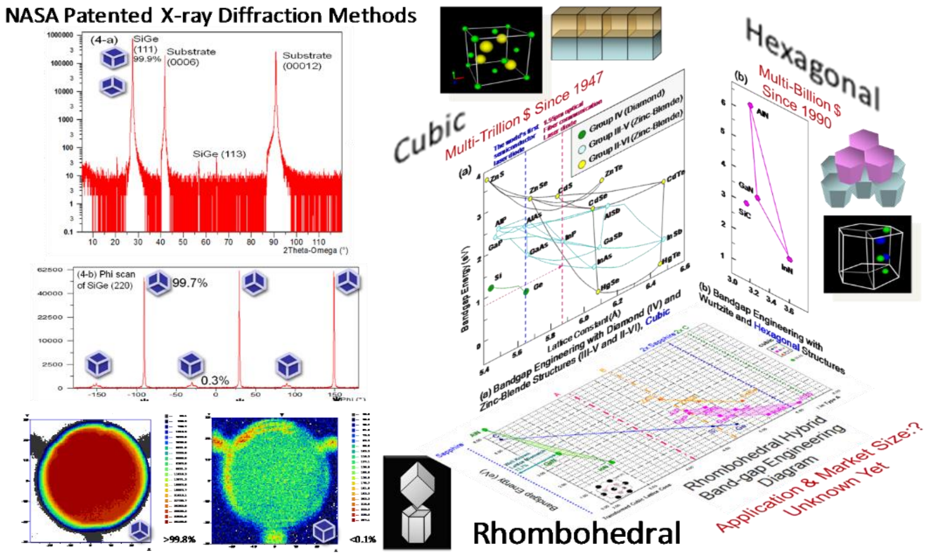
Abstract
New rhombohedral super-hetero-epitaxy technology was developed at NASA. This epitaxy technology enables the growth of unprecedented cubic-trigonal hybrid single crystal structures with lattice match on sapphire (Al_2O_3) substrates, hence with little strain and very few defects at the interface.

Summary
Today's semiconductor industry is based on two bandgap engineering crystal alloy models: cubic and hexagonal crystal structure constraints. New hybrid bandgap engineering based on rhombohedral super-hetero-epitaxy technology was developed by a team of scientists at NASA Langley Research Center in the late 2000s. This technology enables the growth of unprecedented cubic-trigonal hybrid single crystal structure alloys with lattice match on sapphire (Al_2O_3) substrates. This affords minimal strain, and minimal interfacial defects. As a result of this development, a new hybrid bandgap engineering model was generated allowing for thousands of new semiconductor structures to be fabricated (see the figure below). This technology received a prestigious R&D100 award (US) in 2009 and Solar Industry Award (EU) in 2010, and awarded 10 patent and patent applications.

Heteroepitaxy of cubic or zinc blende structures on a trigonal C-plane sapphire substrate presents a considerable challenge in matching lattice constants between the substrate and the host materials. The recently patented Rhombo-Trigonal epitaxy method enables growth of a high-quality single crystalline [111] silicon-germanium layer on a trigonal C-plane sapphire substrate (1-4). However, the process itself requires an unusually high operational temperature to energize the cubic structure enough to be rotated, and deformed into a rhombohedron anchored on a trigonal structure of sapphire. A new mechanism to grow such a rhombohedral epitaxy at a lower substrate temperature has been implemented by energizing the atoms in flux allowing for the reduction of the substrate temperature to a moderate level. The sufficiently energized atoms provide the essential energy needed for the rhombohedral epitaxy process, which deforms the original cubic crystalline structure into a rhombohedron by physically aligning the crystal structure of both materials at a lower substrate temperature. Typically, a strained layer of epitaxy is developed as a precursor structure in order to build a certain thickness level of epitaxy. The newly developed mechanism drastically differs from conventional methods.



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