

Semiconductor Heteroepitaxy

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The quest for high-performance and scalable devices required for next-generation semiconductor applications inevitably passes through the fabrication of high-quality materials and complex designs. The development of the epitaxial growth technique is at the center of these advances. Heteroepitaxy, nowadays, is considered as the elected strategy for integrating semiconductors into heterostructures of high complexity, exploiting the properties of the paired materials, as well as the peculiar effects produced by their coupling. The possibilities are multifarious, starting from the more conventional planar solutions of thin films and going towards fully three-dimensional structures, such as Quantum Wells, Quantum Dots, or Nanomembranes, allowing for the fine tuning of quantum effects. Dealing with dissimilar materials, their combination comes with an additional cost of adapting one to the other, which in the end may turn into defected materials. A great part of the efforts of contemporary research is indeed aimed at mitigating and correcting these issues through new strategies. This Special Issue on “Semiconductor Heteroepitaxy” offers a concise recognition of the most recent attempts of hetero-integration, for both group IV and III-V semiconductors, and of the opportunities offered by the coupling of desired materials on foreign substrates.

Growing Ge on Si is a well-established approach for building integrated heterostructures; however, the misfit between them may result in islanding or defect formation. A well-known technique to obtain Ge and SiGe epitaxial layers on Si requires out-of-equilibrium conditions, i.e., low temperature and fast deposition rate. In the work by Persichetti et al. [1], strain-compensated Ge/SiGe asymmetric coupled quantum wells heterostructures were grown via a chemical vapor deposition technique, demonstrating high structural and interface quality. By means of THz spectroscopy, they demonstrated that it is possible to tune the energy and the spatial overlap of quantum confined subbands in the conduction band of the heterostructures, moving a step toward a working, electrically pumped light-emitting device, monolithically integrated on Si. On the other hand, defects can eventually be an advantage to engineering heterostructure properties. In the work by Spindlberger et al. [2], the intentional implantation of defects during Ge Quantum Dot formation results in an enhancement of light emission. Their approach consists of molecular beam epitaxy, which results in self-assembled Ge Quantum Dots, with the intentional implantation of Ge ions during formation that enhances the optical properties. In this way, both photoluminescence and electroluminescence emissions were demonstrated at room temperature.

The possibility of having monolithic integration of III-V semiconductor devices on Si is highly regarded as a way to exploit the superior opto-electronic properties of III-V materials onto the fully established Si platform, offering low production cost, large scale integration, and full compatibility with present technology. This task, however, requires the process to deal with the substantial lattice and thermal misfits between III-Vs and Si, as well as their dissimilar chemistry, which makes reaching the target quite challenging. This is widely explained in the review paper by Park et al. [3], where the main strategies currently considered to achieve high-quality materials are discussed. Solutions, such as the use of offcut substrates, the confinement of crystal growth by selective area epitaxy and epitaxial lateral overgrowth, the introduction of suitable buffer layers or superlattices,



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as well as thermal annealing cycles, are presented by a comprehensive overview of the literature, analyzing their impact on defects.

The work by Bollani et al. [4] shows a clear example of how some of these approaches could be combined in the growth of GaAs nanomembranes on a plastically relaxed Ge buffer layer deposited on the Si(111) substrate in selective area epitaxy. The key point in the paper is the definition of the growth conditions required to achieve selectivity and regular morphologies, which is shown as being quite critical compared to simple homoepitaxial growth.

Growth of semiconductors on heterogeneous substrates is not only meant for integration purposes but can also be exploited to grow materials of superior crystal quality. This is the case of the work by Hu et al. [5], where the growth of high-quality free-standing GaN is demonstrated by a three-step growth method in Hydrid Vapor Phase Epitaxy (HVPE) on sapphire substrate, thanks to the formation of a GaN polyporous layer.

Conflicts of Interest: The authors declare no conflict of interest.

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