Factsheet 01:
Epitaxy Growth in the Semiconductor Industry

Introduction: Epitaxy, derived from the Greek words "epi" (above) and "taxis" (arrangement), refers to the method of growing a crystalline layer on a crystalline substrate. This technique is pivotal in the semiconductor industry, enabling the production of high-quality materials for various applications, including integrated circuits, LEDs, and solar cells. Epitaxy ensures the creation of uniform, low-defect crystalline layers, which are essential for the optimal performance of semiconductor devices. By aligning the crystal lattices of the epitaxial layer and the substrate, epitaxy enhances the electronic properties and overall quality of semiconductor materials.

Working Principle of Epitaxy Growth

Epitaxial growth involves depositing a crystalline overlayer, known as the epitaxial layer, onto a crystalline substrate. The epitaxial layer aligns its crystal lattice with that of the substrate, ensuring uniformity and high structural quality. There are two main types of epitaxy:

- homoepitaxy (substrate and the epitaxial layer are of the same material, e.g. silicon on silicon)
- heteroepitaxy (deposition of an epitaxial layer of a different material from the substrate)
- The process can be conducted using various methods, each with its own advantages and applications.
- Metal Organic Chemical Vapor Deposition (MOCVD)
- Molecular Beam Epitaxy (MBE)
- Liquid Phase Epitaxy (LPE)

State-of-the-Art in Epitaxy Growth

Epitaxy growth has advanced significantly over the last decades, driven by the demand for higher performance and miniaturization in semiconductor devices. Key advancements include the development of III/V semiconductor materials, such as gallium arsenide (GaAs) and indium phosphide (InP) for optoelectronic applications such as detectors, LEDs and lasers. InP is one of the most important materials for optoelectronics as a direct band gap semiconductor. It is of great interest in photonic integrated circuits (PICs) in the mid infrared region, since it provides enormous potential benefits, including versatile functionality, low-cost, large-area production, and dense integration.

Both Molecular Beam Epitaxy (MBE as well as Metal Organic Vapor Phase Deposition (MOCVD) are well established techniques to produce III-V semiconductor epitaxial layers in low-cost, large area production. They allow exceptional control over the thickness and composition of the epitaxial layer. This level of precision is essential for the fabrication of advanced electronic and optoelectronic devices, such as quantum wells and superlattices.

Challenges in Epitaxy Growth

Despite the progress, epitaxy growth faces several challenges that need to be addressed to fully realize its potential. Monolithic integration of III-V semiconductor devices on Silicon (Si) has long been of great interest in photonic integrated circuits (PICs), as well as traditional integrated circuits (ICs). Both wafer to wafer bonding of III/V and silicon wafers as well as heteroepitaxial growth of III-V semiconductors on Si substrates has been extensively investigated over the years. However, the material dissimilarity between III-V and Si, such as lattice constant, coefficient of thermal expansion, and polarity, introduces a high density of various defects during the growth of III-V on Si.

Future Applications and Potentials for Advancement

Epitaxy growth holds immense potential for future advancements in various fields, driven by the need for higher performance and new functionalities in electronic devices. In quantum computing, high-quality epitaxial layers are essential for the development of qubits and quantum dots. Epitaxial techniques can create defect-free, atomically precise structures that are crucial for the reliable operation of quantum devices.

In advanced photonics, epitaxial growth can create materials with tailored optical properties for use in lasers, photodetectors, and other optoelectronic devices. For example, epitaxial growth of III-V semiconductors, such as gallium arsenide (GaAs) and indium phosphide (InP), enables the fabrication of high-efficiency laser diodes and solar cells. These materials offer superior optical and electronic properties compared to traditional silicon-based devices.

Epitaxy is also pivotal in the development of next-generation electronics, enabling the creation of 2D materials like graphene and transition metal dichalcogenides (TMDs) for ultra-thin, flexible electronics. These materials exhibit unique electronic and mechanical properties, such as high electron mobility and mechanical flexibility, making them suitable for applications in flexible displays, wearable electronics, and advanced sensors.

Horizon Europe Project MILADO

The Horizon Europe project MILADO (Multiwavelength Laser for fast Diagnostic in biomedical and manufacturing application) project, explores cost-effective and scalable epitaxy technology upscale to enable industrial application, addressing the economic and scalability challenges associated with epitaxial growth

Conclusion: Epitaxy growth is a cornerstone of the semiconductor industry, driving innovation and enabling the creation of advanced electronic devices. MILADO aims to pave the way for next-generation electronic devices with superior performance and reliability.

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4 Countries

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