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PROGRESSION OF EPITAXIAL WAFERS AS A KEY FACTOR OF INNOVATIVE GROWTH OF THE COMPLEX SEMICONDUCTOR MARKET

The industry of complex semiconductor compounds is experiencing rapid growth, existing as an independent direction for the creation of new semiconductor devices. This is especially significant for solid-state semiconductor emitters. The main materials for the creation of these devices are solid solutions based on A3B5 compounds. The production of modern micro- and optoelectronic devices (HEMTs, lasers, LEDs, UHF devices) involves epitaxial growth of semiconductor structures on a substrate, which, in turn, determines the requirements for semiconductor wafers. Excellent crystalline quality, minimal lattice mismatch between the growing layer and the substrate material, along with the availability of industrial technologies for producing bulk crystals for their manufacture.

For instance, sapphire (Al2O3) substrates, which were previously rarely used in microelectronics, are now employed in the production of white LEDs. The emergence and growing demand for LEDs have driven significant advancements in sapphire monocrystal development. Its production has increased substantially and continues to grow steadily, similar to trends observed in UHF and power electronics these days. This growth is also mirrored in fields such as solar energy, which requires highly efficient conversion technologies, as well as automotive electronics and radio communication systems.

Another cost-reducing factor is the trend toward larger wafer diameters over time, which correlates with increased manufacturing efficiency and improved device performance. The minimum diameter required for R&D is 2 inches (50 mm), while commercially viable mass production requires a minimum of 4 inches (100 mm), with potential for further increases to 8 inches (200 mm) and 12 inches (300 mm). However, the rate of increase in wafer diameter varies by material, reflecting differences in market demand and the maturity of the technology for each material. For mass production of semiconductor devices, bulk crystal technology for wafers can be a limiting factor. Therefore, having a well-established bulk crystal technology is critical for manufacturing.

However, in parallel with the increase in the wafer diameter, the thickness of the substrates is reduced to minimize the costs of materials and production. When using epitaxial growth technology, which involves the use of high temperatures, for example, nitride technology involves the use of 1000 °C, the growth of epitaxial layers with different crystal lattice parameters leads to the occurrence of stress and bending of the substrates, which without any monitoring leads to deterioration and large variation in parameters over the wafer. To control the stress of the wafers and optimize the epitaxial growth process, it is necessary to improve and optimize the technology with methods for monitoring the parameters of epitaxial layers during the epitaxy process. In particular, silicon and position-sensitive photodetectors are used for precise control of the parameters, which allows achieving high reproducibility of the parameters with high accuracy [2, 3]. The aspects mentioned above indicate the actualization of this issue within the framework of the development of systemic approaches to the integration of intellectualization tools and their influence on the dominant trends in the functioning of market structures [4, p. 247].

As outlined earlier, substrates significantly influence the mass production of semiconductor devices, serving as a key element in this process. To develop both existing and new semiconductor devices, it is necessary to increase investments in new substrate materials, as well as in the development of technologies for producing large-diameter bulk semiconductor materials. Additionally, improvements in epitaxial technologies are required for the fabrication of semiconductor structures on large-diameter substrates, along with the development of diagnostic methods for monitoring the formation of semiconductor layers during the epitaxy process.

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