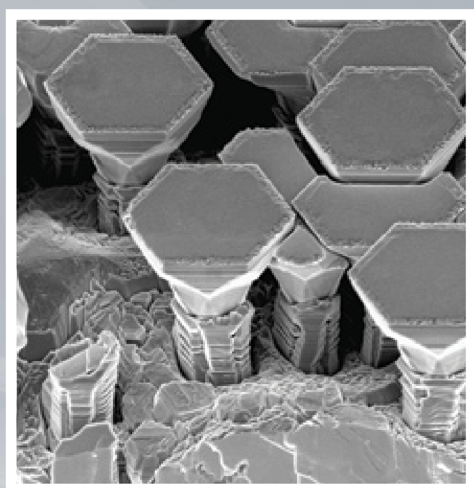
Nano-Column Fabrication for Gallium Nitride Radio Frequency Electronics

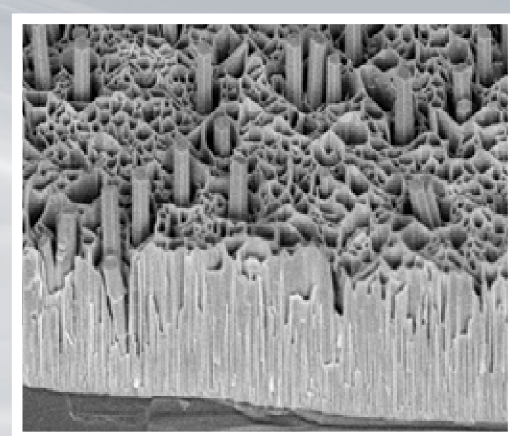
Accomplishment: Gallium nitride (GaN) single crystal substrates with defect densities up to 10,000 times lower than the current state-of-the-art were made using nano-columns as a base layer. The growth technique was demonstrated and characterized in a laboratory environment.



Impact: GaN devices offer significant improvements in elevated temperature operation, resistance to radiation damage, structural integrity and high frequency operation over existing silicon or gallium arsenide semiconductor technologies. These capabilities are essential for radio frequency electronics used for electronic warfare, radar, and communications applications.

Motivation and Approach: State-of-the-art semiconductors used for radio frequency (radar and microwave) electronics are susceptible to radiation damage from electronic warfare countermeasures and in space missions, can fail at elevated temperatures generated by high power devices, and are susceptible to damage from mechanical vibration. GaN offers significant improvements in these environments, and also operates at higher frequencies, giving more efficient data transfer and more secure communications. Like existing semiconductors, GaN must be grown as single crystals for high quality electronics. Despite more than a decade of research, techniques to grow GaN single crystals give a high number of defects that significantly degrade performance, reliability and lifetime, forming a significant barrier to application of this technology.

This accomplishment validates the critical first step for producing large, high quality single crystal GaN crystals with defect densities 10,000 times lower than previously possible. A layer of aluminum nitride less than 150 nanometers thick is deposited on commercially available silicon or sapphire single crystal wafers. GaN nano-columns 100 nanometers in diameter with very low defect densities are grown on the aluminum nitride using molecular beam epitaxy, a commercial fabrication process, to carefully control the nano-column size, orientation and spacing. The vertical nano-column growth is transformed to lateral growth by switching to a second commercial processing technique, metal-organic chemical vapor deposition. This lateral growth produces GaN plateaus that are up to 10 microns in diameter and have the same low defect density as the underlying nano-columns. Joining plateaus to form a very large single crystal substrate is the next step and is currently underway. A path toward foundry-class electronics fabrication is being pursued through collaboration with Kyma Technologies.



Team: This work was performed by Dr. John Albrecht (Sensors Directorate), Dr. Kent Averett (Materials and Manufacturing Directorate) and Prof. Chih-Chung Yang (National Taiwan University). Funds were provided by the Air Force Office of Scientific Research through in-house research tasks (Dr. Don Silversmith, Program Manager) and through the Taiwan Nanoscience Initiative (Dr. Harold Weinstock, Dr. Don Silversmith and Dr. Jim Chang, Program Managers). Kyma Technologies is funded through the Small Business Innovation Research (SBIR) program.