May 15, 2024

Thin Film Lithium Niobate (TFLN)

Policy Paper

Thin film lithium niobate (TFLN) is quickly becoming one of the most promising materials for next-generation telecommunication devices as well as integrated photonics, which will enable numerous future technologies such as quantum computing, quantum sensing, high-frequency modulators, and LiDAR. In addition, there is growing consensus in the telecommunications and hyperscale industries that TFLN will become a key enabler of the 1.6 and 3.2 terabit optical switches and interconnects. This means that as consumers strive for faster and better service, TFLN will be essential.

Modulators built using TFLN are not only highly efficient since they consume very little power, but also, they are capable of operating with an extremely high bandwidth (approximately 250 Gbaud) and with lower insertion losses compared to most other contenders. Furthermore, TFLN devices hold the promise of significantly reducing the overall device size, thereby further aiding the long-heralded heterogeneous integration and optical packaging. The current market for TFLN is $190 million and is projected to grow at a CAGR of 39.2% to $1.93 billion by 2029. TFLN is already highly valuable, and a six-inch chip can yield over $3 million in revenue. This growth is driven by the demand in the telecom, hyper-scaling and artificial intelligence, and RF communications industries.

Currently, TFLN is only available in limited supply, coming directly from China, because it is extremely difficult to create or "exfoliate" TFLN wafers. Because the supply chain is so limited, large-scale semiconductor companies have not yet deployed TFLN lines. However, Quantum Computing Inc. (QCi), an innovative quantum optics and nanophononics technology company, is the only company in the United States capable of processing 150mm wafers. The QCi TFLN fab is equipped with both front and as well as backend optical packaging capabilities, thereby creating significant market and technology opportunities.

QCi will open a fully commissioned TFLN fabrication facility by Q4, 2024 in Tempe, Arizona. In the first full year of production, the company will be capable of producing over $180M in sellable product. As of March 2024, QCi has secured its first offtake agreement with Comtech Telecommunications Corporation to produce wafers for its satellite communications. QCi's U.S.-based foundry will enable components and integrated circuits for electro-optic modulators (OEM), frequency converters, periodically poled structures, and photonic integrated circuits (PIC).

What does this mean for advanced technologies in the United States? Similar to the evolution of silicon technologies which started in the 1940's, TFLN is promising to become "the silicon of the future." Just as decades ago, data scientists of today recognize the need to transmit information and energy more efficiently as well as the need to develop new materials to address these future requirements.

The disruptive technological advancement, which will be enabled photonic integrated circuits that build on the TFLN platform, is comparable to the developments and innovations in the 1970's that led to the advancement of Complementary Metal Oxide Semiconductor (CMOS) architectures, which paved the way for the integrated circuits we use today and serve as the foundation of the technology we use to create chips for microprocessors, microcontrollers, memory, and all digital logic circuits.

Driven by the fact that demand for faster, more efficient processing systems will continue well beyond the current capacity of silicon, TFLN devices will spearhead the way for the future needs of ultrafast telecommunication networks and advanced connectivity.

Emerging and nascent technologies require high-frequency modulators (switches) to achieve future technological objectives. Computing systems which use silicon chips seem like dinosaurs compared to TFLN nano photonics-based systems.

To achieve the speed and boost processing capabilities that the market demands, photonic-based computing machines which are being developed by QCi are leveraging entropy, and non-linear feedback instead of electrons. These machines, which QCi has recently begun deploying, use lithium niobate instead of silicon for performing computational tasks. Using light instead of electricity is a key technological enabler likely to usher in a disruptive era of innovation.

Recently, scientists all over the world, including at QCi, have demonstrated the ability to encode large amounts of information onto single photons. The ability to densely encode information onto photons and confine them to very small spaces make them ideal for use in next generation optical computing engines. Furthermore, since photons produce virtually no heat, they are ideal for use in demanding computing applications. For example, nearly 43% of all energy used by large-scale computing facilities is spent on cooling. Today, that is a staggering 110 Terawatts Hours of electricity which is used annually simply to cool data centers. Photons in action generate no heat. As a result, photonic-based systems cannot overheat like electronic systems. Not only does this make photonic-based systems cheaper and easier to operate, but also, they generate less “noise” or distraction from computational efforts because they are not generating heat.

Just as silicon and CMOS allowed electronic components to move from large vacuum tubes to billions of transistors on a single chip, photonic-based systems built using TFLN will unlock the next generation of advanced technology. TFLN is special because it is highly nonlinear and efficient, useful for switching and modulation, creates minimal amounts of noise, and has wide and efficient optical bandwidth. Top innovators like Northrup Grumman, Raytheon, Samsung, IBM, Cisco, Dell, and Qualcomm are all exploring TFLN, while at the same time their global competitors like China Mobile, Tencent, and Nippon Telegraph and Telephone compete for access and deployment of TFLN and photonic technology.