Single Crystal, High Quality Gallium Nitride Substrates For Solid-State Lighting and the Electrical Utility Grid

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Technology

All thin-film opto/electronic devices (e.g., LEDs, transistors, power switches, and lasers) are fabricated by vapor deposition methods onto single crystal substrates. The properties and quality of the substrate dictate the device performance. Historically, new semiconductor materials have gained wider market penetration as the quality, area, and cost of the native substrate have improved. Gallium nitride (GaN) has unusual materials characteristics that enable it to perform well enough to penetrate specialized niche markets despite the extremely high defect density present in the material due to the lack of availability of a native substrate; however, like its III-V predecessors, its true potential will be realized only when an economical, high quality, large area native substrate becomes readily available.

However, GaN is a particularly challenging material to grow in bulk by traditional growth methods because the very properties that make it so attractive are exactly those which make it difficult to grow. It requires diamond-like conditions for melting (2500C at 60,000 atm), it is chemically inert, and it decomposes before it melts. Most alternative approaches aren't scalable or high throughput; others are limited by quality. All are very expensive. A new method for bulk crystal growth is required for this material.

The Electrochemical Solution Growth method (ESG) is a novel approach being developed by SNL. It attacks the fundamental limiting factor common to all other growth approaches in a unique way, by electrochemically generating a reactive form of nitrogen *at atmospheric pressure in solution.* One gallium ion is generated for every nitride ion, precisely the ratio needed for GaN growth. Solution growth techniques produce the highest quality material (~10^2 dislocations/cm^2). Borrowing well-developed concepts from Rotating Disk Reactor MOCVD technology, the reactants are delivered to a rotating seed crystal (see Figure 1). This technique is fully scalable. A single-crystal boule may be pulled from the surface. The growth rate is high for high throughput and low cost. If successful, it will meet industry's needs.

Markets

Market data for a bulk GaN substrate that meets the community's needs is difficult to predict due to its utter absence in the community. Hundreds of millions of dollars have been spent developing work-arounds for not having a suitable substrate. However, the existing failure of GaN to penetrate markets to its full potential is one loud testament to the impact that a high quality substrate would have on the industry. ESG is an enabling technology and will break open entirely new markets.

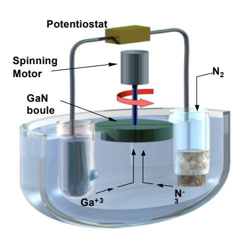
Fully-Adopted Solid-State Lighting Diode Market: $80 Billion
Substrate Cost is ~8% = $6.4 Billion

- *Green LEDs (general illumination):* An enabling substrate could capture ~$150M by 2014.
- *Display Backlighting:* Opportunities exist to improve yields. Current estimates are small today (~$50M) but could grow to $200M by 2014.
- *Lasers for BluRay:* This small market (~$50M in 2011) has the highest need for high reliability, which is governed by quality, where dislocation densities in the 10^3/cm^2 range would provide significant advantage over current technology. The significance lies in the fact that these manufacturers recognize the impact of defects at high current densities, which is where the rest of the devices are ultimately headed.

Our Future, With a Suitable GaN Substrate

The value proposition of this technology lies both in what exists already, but becomes more enticing when considering the existing limitations of the technology that this would help overcome. Conservative estimates multiply current figures by a factor of 10X; optimistic spectators place it much higher, possibly 30-50X (see Figure 2).

Figure #1



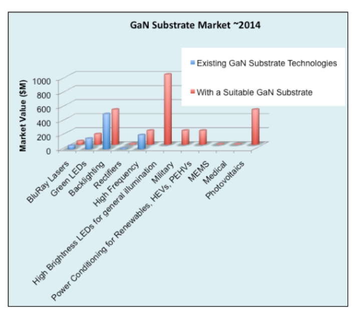
Commercial Readiness

The ESG technology is early-stage and our strategy for raising maturation capital consists of a combination of mostly government investment supplemented by private investment. Private investment ensures a pull from industry, which helps encourage government involvement and provides an early-stage economic opportunity for private investors.

Funding to date has been small and intermittent, and entirely by government sources. However, using these funds, all of the components of the technology have been investigated and demonstrated. What remains is to integrate all concepts into a single growth chamber, which needs to be fabricated.

The technology considered by one investor to be "The Solution" to the substrate problem. Millimeter-sized crystals have been grown at atmospheric pressure in under 2 hours in unoptimized conditions. The nitrogen electrochemistry is the novel innovation, and confidence has been developed in that reaction by electrochemists at Sandia. The full-time effort required to reach a go/no-go answer on the viability of the technology and bring it to a private equity position is estimated to be 6-9 months.

Figure #2



Sources of Market Info

1. **C. Wade Sheen, BriteGaN, personal communication. His sources:**
2. **Yole Developpement SARL, 2009**
3. **CanaccordAdams, 2009**
4. **Strategies Unlimited, 2009**

Intellectual Property

ESG is a patented process by Sandia National Labs (US7435297, "Molten Salt Based Growth of Group-III Nitrides") and is available for licensing. The patent covers the concepts in the ESG process. There exists ample opportunity for capturing further IP around this patent as the technology develops.

Some examples of lighting applications

Samsung 42" LED TV

Audi LED Headlamps

AEON Lighting LED Lighting

Personal LED DVD Player

Navigation Displays

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