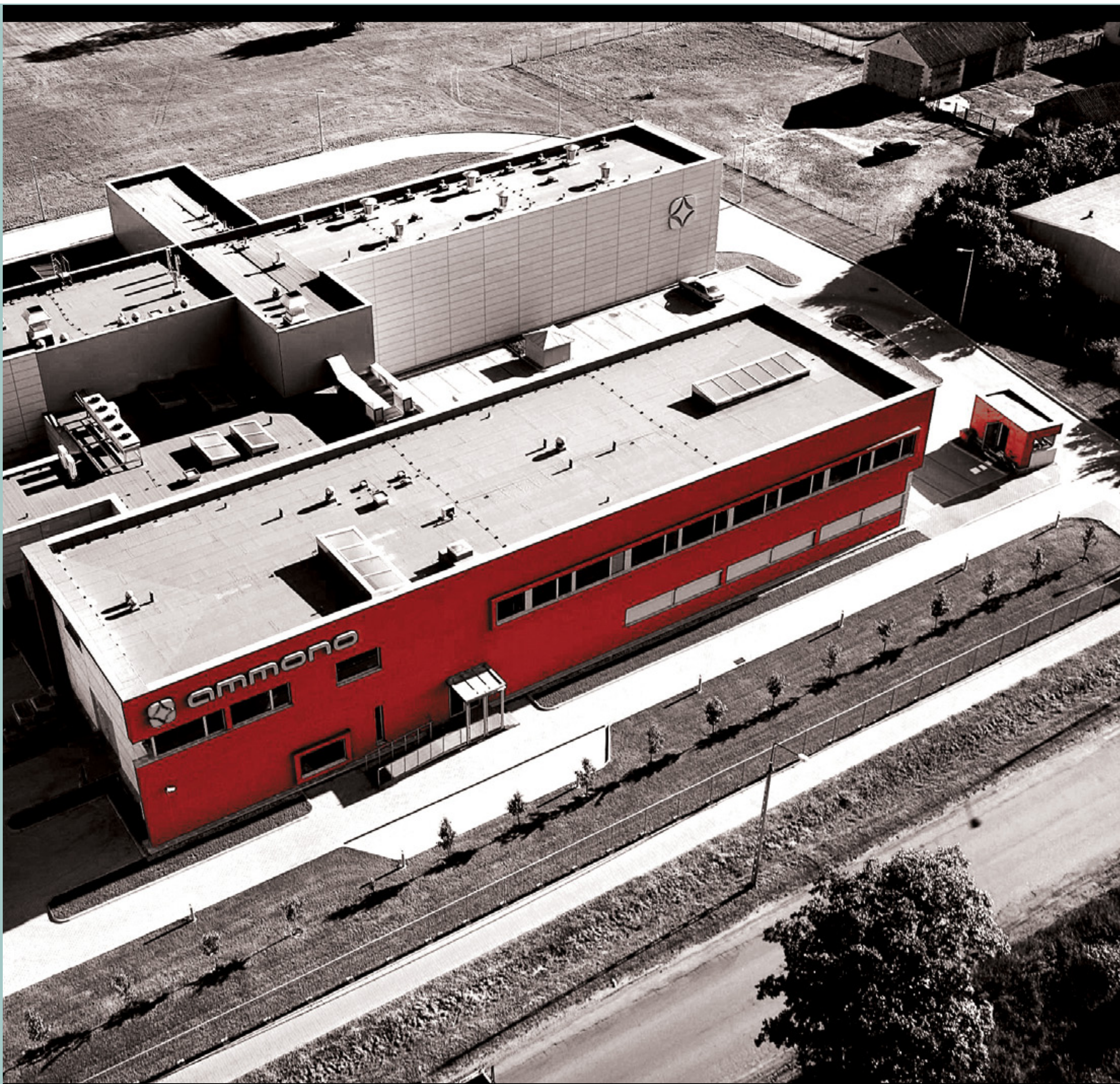


Laser Vision

One day, not long from now, your iPhone will function as a movie projector. When you snuggle into bed to watch the latest Hugh Grant rom-com on the wall of your bedroom, you may have a company on the fringe of Warsaw to thank.

BY PARKER SNYDER

PHOTOGRAPHY BY AMMONO

> "Gallium nitride crystals may enable the next generation of fuel-efficient cars and energy-efficient lighting."

ROBERT DWILIŃSKI had an idea. Grow a crystal, slice it into pieces, and use the pieces to grow other crystals. It's not a new idea at all. It's rather a common technique for growing crystals for use in semiconductor electronics and solid-state lighting.

But Mr. Dwiliński did it with a less common material - gallium nitride (GaN) - and this feat has caused quite a stir in the electronics world. Ammono may one day introduce the market for crystals used the next generation in semiconductors.

AMMONO, EXPLAINED

As early as 2007, no one had even heard of the small Polish company. In July of 2010, Mr. Dwiliński's story then appeared on the cover of IEE Spectrum, an imprint owned by the largest technology association in the world. Since then, he's been something of a crystal-growing rock star.

Why does Mr. Dwiliński believe that the future of semiconductors is gallium nitride? It has much to do with laser optics, a potential market for his technology. When a beam of electrons comes into contact with a gallium nitride crystal, visible light gets produced in the green and blue spectrum. Because gallium nitride crystals produce their light at relatively low heat, they are thought to be suitable for the next generation of LEDs (light emitting diodes).

Gallium nitride crystals could be embedded in ordinary consumer electronics, such as mobile phones. The iPhone of the future, for instance, could use gallium nitride in movie-projector technology. These crystals might also be used in car electronics to extend battery life. For these reasons, the technology may be a building-block in Europe's conversion to a low carbon economy.

But Mr. Dwiliński isn't convinced his gallium nitride crystals should be sold as an environmental technology, although he recognizes they may enable the next generation of fuel-efficient cars and energy-efficient lighting. For the time being, he just wants to grow his business. Cleantech Poland spoke to him at the Eurecan European Venture Capital contest, for which Ammono won first place in the cleantech division.

SMALL COMPANY, BIG AMBITIONS

Mr. Dwiliński is CEO and co-founder of Ammono, a company seated on the outskirts of Warsaw in the village of Nieporęt. He and his staff of 50 or so employees have been producing GaN crystals since 1993, the year they proved this certain crystal could be obtained in small quantities at high quality.

At a glance, synthetic crystals in semiconductors seem to be ubiquitous. Take a drive through Warsaw's city-center, and at the main roundabout, there's a large LED screen made by Samsung. According to Mr. Dwiliński, the screen is made up of millions of LEDs based on synthetic sapphire. Ammono is developing crystals based on gallium nitride, which he sees as a preferable alternative.

LED television screens are just one of the market segments he's targeting with his crystals. The biggest market, according to Mr. Dwiliński, is in electric vehicles, for use in models such as the hybrid Toyota Prius or the GM Volt. Conventionally, electric cars convert direct current into alternating current through the use of a power inverter. Inverters limit the range of electric vehicles because the electronics, based on silicon, need expensive and heavy cooling equipment.

According to Mr. Dwiliński, an inverter base on gallium nitride technology would "double the battery life" of a hybrid or electric car. He estimates the potential car market at several million gallium nitride wafers per year, as each car consumes a wafer.

At current prices, a 4-inch (102 mm) wafer based on gallium arsenide, a competing technology, costs about €141 ($200). A wafer based on gallium nitride exceeds €3,500 ($5,000) for a 2-inch (51 mm) wafer - nearly 80 times the price.

Mr. Dwiliński believes gallium nitride would be commercially viable at $1000 for a 2-inch wafer, and as Ammono ramps up production, economies of scale would bring the price down further.

CRYSTAL-CLEAR HISTORY

Mr. Dwiliński was inspired by a lecture from Izabella Grzegory, a professor with the High Pressure Research Center at the Polish Academy of Sciences.

Ms. Grzegory went on about the outstanding qualities of a family of nitrides whose properties were well-suit-

> "Competing technologies rely on hydride vapour phase epitaxy, which can produce crystals quicker, but of a lower quality."

ed for electronics. That lecture was the seed of inspiration that led Mr. Dwiliński to pursue GaN crystal production. Later Mr. Dwiliński did his PhD studies under Maria Kamińska at the University of Warsaw. In founding Ammono, he was joined by Leszek Sierzputowski, a chemist, Roman Doradziński, a theorist, and Jerzy Garczyński, an autoclave technician.

By 1993, the four research scientists had produced microscopic deposits of gallium nitride, a promising development, because when the crystals were exposed to a laser they lit up via a process called photoluminescence. This meant that the crystals were relatively free from defects.

Mr. Dwiliński's chose the ammonothermal process (from which Ammono gets its name): a bulk gallium nitride poly mix is suspended in an autoclave filled with ammonia gas. Autoclaves are machines that regulate temperature and pressure.

Over time, the gallium nitride feedstock gets deposited layer by layer on seed crystals, replicating whatever base structure to which it adheres. Good seeds are important because they form the base, and that's why Ammono spent years developing super-high quality crystals.

Early on, Mr. Dwiliński wanted to scale production. However, with no domestic venture capital to fund operations, Ammono had to cooperate with Nichia Corporation, a Japanese firm, who retains 30 percent ownership and a stake in the intellectual property.

The crystals Ammono produces today include 2 inch (51 mm) diameter bulk C-plane substrates and non-polar M-plane. Ammono also produces A-plane and semi-polar gallium nitride wafers. The polar/plane designation refers to the atomic orientation of the crystal. It was the 2 inch crystals that caught the attention of the electronics industry.

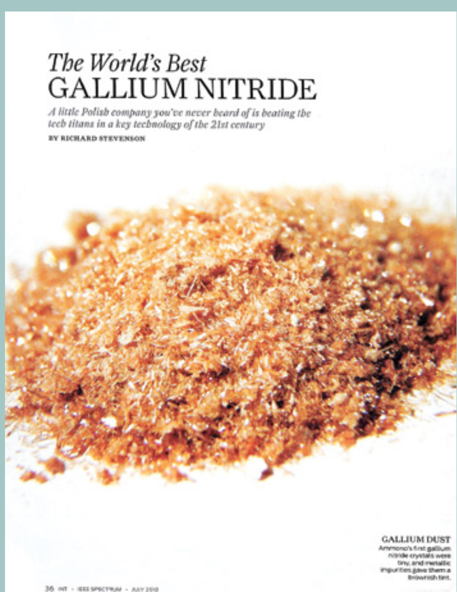
THE $10 MILLION QUESTION

Until 2007, Mr. Dwiliński was rather quiet about his activities, partly because Polish scientific circles tend to eschew publicity, but also because Mr. Dwiliński had to sign for non-disclosure with Nichia Corporation until his crystal technology had matured.

Today, he's seeking private equity or debt financing. Because crystal production depends on the autoclaves - the more autoclaves, the more crystals - Mr. Dwiliński says he'd use €7 million ($10 million) to develop production capacity of his 2-inch wafers. The Ammono campus covers 4 ha (10 acres), which is ample enough room for the 8 manufacturing halls housing 20 autoclaves which Ammono aims to build.

Ammono isn't the only ones racing to develop the next generation of synthetic crystals for use in semiconductors and lighting. Competing technologies rely on hydride vapour phase epitaxy (HVPE), which can produce crystals quicker, but of lower quality.

Mitsubishi Chemical Corporation, Asaki Kasei and Momentive Performance Materials are among the companies at work on a competitive product, but according to Mr. Dwiliński, they are still early in production.



SOURCE: IEEE SPECTRUM MAGAZINE