November 19, 2021

Confirmed growth of 4-inch GaN Crystal at the World's Largest Demonstration Facility for Manufacturing GaN Substrates
—Contributing to the development of ultra-high-efficiency devices, scheduled to start market supply in FY 2022—

The Japan Steel Works, LTD.

Mitsubishi Chemical Corporation

The Japan Steel Works and Mitsubishi Chemical Corporation are working on the demonstration and development of large-diameter bulk gallium nitride (GaN) substrates for power electronics under NEDO's "Strategic innovation program for energy conservation technologies." The demonstration and development took place at the world's largest demonstration facility for manufacturing GaN substrates (large-scale demonstration facility), established in May 2021. We conducted experiments of crystal growth for the mass production of 4-inch GaN substrates using "SCAAT™-LP," a low-cost manufacturing technology for high-quality GaN substrates. As the result of the experiments, we have confirmed that 4-inch GaN crystals are growing as planned.

The large-scale demonstration facility has been significantly scaled up compared to a pilot facility, making it possible to manufacture a large amount of GaN substrates. Going forward, we will conduct further demonstration experiments at the large-scale demonstration facility with the aim of contributing to the development of ultra-high-efficiency devices through the stable supply of high-quality GaN substrates and start market supply in early FY 2022.

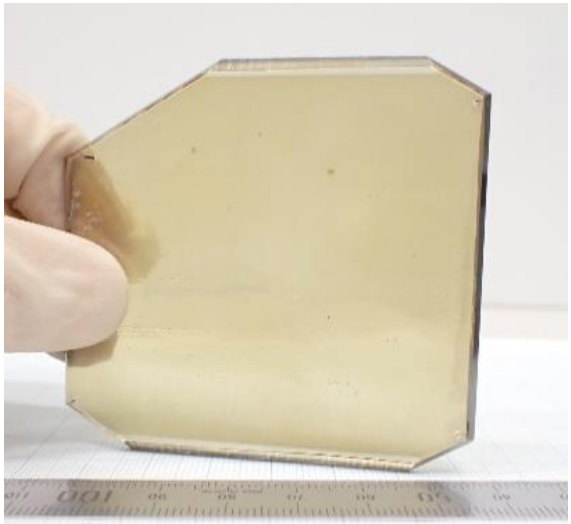


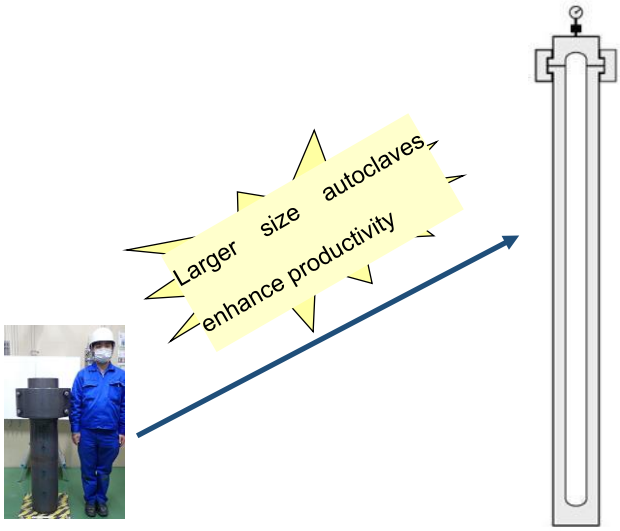
Fig. 1: GaN crystal grown with "SCAAT™-LP"

1. Overview

Gallium nitride (GaN) is a material used to create ultra-high-efficiency devices with high durability. The devices are expected to mitigate environmental burdens as they help reduce CO_2 emissions by slashing power consumption. For this reason, GaN has the potential to be applied not only to high-brightness and high-power lasers, high-efficiency illumination and new-generation displays, but also to various fields, including telecommunications and power semiconductors.

Against this background, under the "Next generation power electronics project for achieving a low carbon consumption society[*1]," a grant project by the New Energy and Industrial Technology Development Organization (NEDO), The Japan Steel Works, LTD. (JSW) and Mitsubishi Chemical Corporation (MCC) worked at a pilot facility constructed in the Muroran Plant of Japan Steel Works M&E, Inc. (Muroran City, Hokkaido) from FY2017 to FY2019 to develop SCAAT™-LP, a low-cost manufacturing technology for GaN substrates to achieve high quality and high productivity using MCC's unique Super Critical Acidic Ammonia Technology (SCAAT™), and confirmed uniform crystal growth on 4-inch substrates. The pilot facility is characterized by having high-temperature and high-pressure autoclaves[*3] (pressure vessels) to realize crystal growth using the low-pressure acidic ammonothermal method[*2] and takes advantage of JSW's abundant experience in manufacturing pressure vessels.

In addition, under NEDO's grant program started in FY 2020 "Strategic Innovation Program for Energy Conservation Technologies,"[*4] JSW and MCC are also conducting verification tests for the mass production of 4-inch GaN substrates using SCAAT™-LP at the large-scale demonstration facility we introduced for the project. The significant scaling up of the autoclaves compared to the pilot facility enabled the mass production of GaN substrates, and we have confirmed that GaN crystals grow to 4 inches as planned.



Autoclave at the pilot facility　　Autoclave at the large-scale

Fig. 2: Image of large autoclave

2. Achievements

<Overview of demonstration facility>

-Location: Muroran Plant of Japan Steel Works M&E, Inc.

-Total area: 266 m^2

-Major equipment: Large autoclave units, heaters and controllers, ammonia supply/absorption equipment, high-purity gas purifiers

(1) Smooth operation of the large-scale demonstration facility

JSW and MCC have operated the large-scale demonstration facility since May 2021 and confirmed through multiple crystal growth experiments that the facility is operating steadily as planned. At the same time, we confirmed no problems in safety and productivity in the series of crystal growth processes, including the setting of raw materials and seed crystals in autoclaves in advance; supplying the solvent ammonia; increasing, maintaining and decreasing the temperatures in autoclaves; the process of retrieving the crystals; and any other processes.

(2) Confirmation of crystal growth on 4-inch GaN substrates

JSW and MCC are conducting crystal growth experiments using the large-scale demonstration facility and have confirmed that we can grow GaN crystals on a 4-inch GaN seed crystal. We have also confirmed that GaN crystals grow throughout the crystal growth field through a long-time operation of autoclaves and that SCAATT™-LP, a crystal growth technology we developed at the pilot facility, works well at the large-scale demonstration facility.

3. Future plan

In the future, JSW and MCC will continue crystal growth experiments at the large-scale demonstration facility to achieve higher productivity and start market supply in early FY 2022.

We are dedicated to contributing to the development of ultra-high-efficiency devices by supplying high-quality GaN substrates, which are regarded as essential material to support future society.

The part of fundamental research that serves as the foundation of the achievements is based on the results of the Tohoku University Business Incubation Program (BIP)[*5] supported by the Public-Private Innovation Program from the Ministry of Education, Culture, Sports, Science and Technology.

Since 2012, JSW, MCC, and the Chichibu Lab at the Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, have collaborated to develop the technology to manufacture large-diameter high-quality and low-cost GaN substrates and established the fundamental technology for future mass production called the low-pressure acidic ammonothermal method (LPAAT method).

Annotations

[*1] Next generation power electronics project for achieving a low carbon consumption society

Research and development item: Development of technology that accelerates the practical application of GaN powered devices etc./Development of innovative technology for manufacturing GaN wafers (grant project)

Project period: FY 2017 to FY 2019

Project overview: https://www.nedo.go.jp/activities/ZZJP_100011.html

[*2] Low-pressure acidic ammonothermal method

This technology consists of a solvothermal method in which a solute that is not dissolved at ordinary temperature and pressure is dissolved in a high-temperature and high-pressure supercritical fluid and is recrystallized on a seed crystal by utilizing the difference in solubility depending on the temperature gradient in the furnace. Acidic mineralizers such as ammonium halide (NH4X, X=F, Cl, Br, I) are used as mineralizing agents to promote the dissolution of GaN in supercritical ammonia. They facilitate crystal growth under relatively low-pressure conditions (approx. 100 MPa, about half of that using conventional technology), thus enabling the realization of a large-scale manufacturing facility suitable for the mass production of large-diameter GaN substrates.

[*3] Autoclave

An autoclave is a pressure vessel capable of accelerating chemical reactions by increasing the internal pressure. Materials applied to the device are pressure resistant and are not corroded by chemical reactions. Autoclaves range in size from tens of centimeters to large devices up to tens of meters.

[*4] Strategic innovation program for energy conservation technologies

Research and development item: Demonstration and development of large-diameter bulk GaN substrates for power electronics (grant project)

Project period: FY 2020 and FY 2021

Project overview: https://www.nedo.go.jp/activities/ZZJP_100039.html

[*5] Tohoku University Business Incubation Program (BIP)

FY 2015 to FY 2017: “Demonstration of GaN Substrates for High-Efficiency Laser Diodes and Power Switching Devices with High Energy Conversion Efficiency using the Acidic Ammonothermal Method”

4. Contact

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