New Product Information Session for FY2018 (Ended March 2019)

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NGK INSULATORS, LTD.
Today’s presentation
Iwao Ohwada
General Manager,
ADC (Advanced Device Components) Division

● Chip-type Ceramic Secondary Batteries “EnerCera®” Series
  ✓ Outline, lineup, application development, expected sales
● Wafer-related Products — Outline and Future Prospects
  ✓ Bonded wafer
  ✓ Gallium Nitride (GaN) wafer “FGAN®”
EnerCera® Pouch

- Ultra-thin and bendable battery that can be embedded in IC cards etc. (Thickness: 0.4 mm)
- Applicable to hot lamination process, which is the standard method of manufacturing cards.
- Also capable of fast charging corresponding to contactless card reader

EnerCera® Coin

- Coin-type battery that can be mounted on circuit boards by reflow soldering (Thickness: 1 mm or more)
- Constant-voltage-charging capability eliminates the need for a charger IC.

Both “EnerCera Pouch” & “EnerCera Coin” win CES 2019 Innovation Awards as innovative secondary batteries that will expand the IoT device market.
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## Lineup of Chip-type Ceramic Secondary Batteries “EnerCera®” Series

<table>
<thead>
<tr>
<th>Model No.</th>
<th>EC382504P-P</th>
<th>EC382704P-C</th>
<th>EC382704P-H</th>
<th>ET271704P-H</th>
<th>ET1210C-R</th>
<th>ET2016C-R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions (mm)</td>
<td>38 x 25 x 0.45t</td>
<td>38 x 27 x 0.45t</td>
<td>38 x 27 x 0.45t</td>
<td>27 x 17 x 0.4t</td>
<td>Φ12 x 1.0t</td>
<td>Φ20 x 1.6t</td>
</tr>
<tr>
<td>Capacity (mAh)</td>
<td>20</td>
<td>27</td>
<td>20</td>
<td>5</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>Nominal Voltage (V)</td>
<td>3.8</td>
<td>3.8</td>
<td>3.8</td>
<td>2.3</td>
<td>2.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Energy density (mWh/cc)</td>
<td>180</td>
<td>220</td>
<td>170</td>
<td>70</td>
<td>100</td>
<td>115</td>
</tr>
<tr>
<td>Constant voltage charging</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>OK (10 min/80%)</td>
<td>OK (25 min/80%)</td>
<td></td>
</tr>
<tr>
<td>Peak discharge current (mA)</td>
<td>500</td>
<td>250</td>
<td>200</td>
<td>150</td>
<td>25</td>
<td>60</td>
</tr>
<tr>
<td>Operation temperature (recommended)</td>
<td>0ºC-45ºC</td>
<td></td>
<td></td>
<td></td>
<td>-20ºC-60ºC</td>
<td></td>
</tr>
<tr>
<td>Heatproof temperature (in process)</td>
<td>80ºC (Cold lamination is available)</td>
<td></td>
<td>135ºC (Hot lamination is available)</td>
<td></td>
<td>260ºC (Reflowable)</td>
<td></td>
</tr>
</tbody>
</table>

### Pouch
- Appearance: Weight (g) 0.7g, 0.8g, 0.8g, 0.3g, 0.5g, 2.0g
- Major applications: Long-distance wireless communication card, Biometric card with fingerprint authentication, using dedicated charger, Biometric card with fingerprint authentication, not using dedicated charger (Charged during settlement process), IoT module (Smart key, RFID tag, electronic shelf label, wrist watch, backup power source, etc.)

### Coin
- Appearance: Weight (g) 0.7g, 0.8g, 0.8g, 0.3g, 0.5g, 2.0g
- Major applications: Long-distance wireless communication card, Biometric card with fingerprint authentication, using dedicated charger, Biometric card with fingerprint authentication, not using dedicated charger (Charged during settlement process), IoT module (Smart key, RFID tag, electronic shelf label, wrist watch, backup power source, etc.)
The IoT device market is expanding to realize an IoT society where all things are connected to the Internet. The market size is expected to reach 30 billion units by 2020.*

Aim to expand the business with EnerCera® series as the compact/thin power source for IoT devices.

* FY2018 white paper on telecommunications by the Ministry of Public Management, Home Affairs, Posts and Telecommunications
Mass-production lines for monthly production of 2 million units have been introduced. Mass-production starts sequentially from April 2019.

Reference: Smart card market trends

- The world total amount of damage caused by fraud use of credit cards and debit cards is about 2.3 billion dollars (2016)\(^*1\).
- The economic loss in the U.S. due to leakage of IDs is about 1.7 billion dollars (2017)\(^*2\).
- In this situation, a new smart card with a thin secondary battery embedded has appeared.
  - High-security credit card with fingerprint authentication function
  - High-security and convenient multi-functional payment card with wireless communication function, display, etc.
  - ID card with fingerprint authentication for foreign worker management and workers of high-security institutions such as government agencies.
- It is estimated that the market size will expand from about 10 million cards in 2019 to 270 million cards by 2025.\(^*3\)

\(^*1\): Nilson Report in October 2017 \(^*2\): Javelin Strategy & Research 2018 \(^*3\): Our estimate based on ABI Research 2017
Bonded wafer manufactured by bonding single crystal, ceramics, etc. with characteristics different from each other using NGK’s original technology. By combining different features of each material, the bonded wafer helps to improve the performance of a high-frequency filter (SAW filter) for smartphones etc.

**Bonded wafer**

**Structure**
- Wafer A (functional layer)
- Wafer B (base)

**Diameter**: 4, 6 inches

**SAW filter**
- Smartphone
- Ceramics package substrate (a few mm square)

**Effects of bonded wafer**

**No bonding**
- Lithium Tantalate (Thermal expansion coefficient: Large)

**Bonded wafer**
- Silicon (Thermal expansion coefficient: Small)
- Characteristics of the SAW filter change as the electrode pitch changes due to temperature shift. The bonded wafer prevents dimensional change due to temperature and stabilizes the characteristics of the SAW filter.

Because the band space of the filter with bonded wafer is narrow, frequency bands can be laid out closely to each other and frequencies can be used efficiently.
As services of the 5th-generation communication system (5G) start, demand for the bonded wafer will increase because higher frequencies are to be used and higher performance is required for the filter.

**Spread of 5G**

<table>
<thead>
<tr>
<th>Features of 5G</th>
<th>4G</th>
<th>5G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large capacity</td>
<td>1 Gbps</td>
<td>10 Gbps</td>
</tr>
<tr>
<td>Multi-connection</td>
<td>100,000 devices/km²</td>
<td>1 million devices/km²</td>
</tr>
<tr>
<td>Low delay</td>
<td>10 msec</td>
<td>1 msec</td>
</tr>
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</table>

**Required performance of filter**

<table>
<thead>
<tr>
<th></th>
<th>4G</th>
<th>5G</th>
</tr>
</thead>
<tbody>
<tr>
<td>Higher frequency</td>
<td>~3 GHz</td>
<td>~6 GHz</td>
</tr>
<tr>
<td>Band space *¹</td>
<td>20 MHz~</td>
<td>10 MHz</td>
</tr>
</tbody>
</table>

*¹: In the case of middle band

**Applicable range of bonded wafer**

- SAW filter (Bonded wafer)
- BAW filter *²
- SAW filter (No bonding)

**Expected sales**

- *¹: Lower band
- *²: BAW filter: Filter with a complicated structure manufactured in the thin-film process
Outline of Gallium Nitride (GaN) wafer “FGAN®”

We provide high-quality and low-defect GaN wafers realized with our original crystal growth technologies (liquid phase crystal growth method). They are used in semiconductor lasers that are in greater demand as a substitute light source for mercury lamps because of regulations on the use of mercury required by the Minamata Convention on Mercury.

**Appearance of FGAN®**

**Dislocation density:** $10^5$/cm$^2$

**Conventional product** (GaN crystal grown by HVPE method)

**Dislocation density:** $10^7$/cm$^2$

*Method to detect defects in crystal as dark dots

**Application examples**

- Business projector
- Headlamp with light distribution control

**Expected sales**

Approx. 10 billion yen

<table>
<thead>
<tr>
<th>Year</th>
<th>Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>'20/3</td>
<td></td>
</tr>
<tr>
<td>'21/3</td>
<td></td>
</tr>
<tr>
<td>'22/3</td>
<td></td>
</tr>
<tr>
<td>'23/3</td>
<td></td>
</tr>
<tr>
<td>'24/3</td>
<td></td>
</tr>
<tr>
<td>'25/3</td>
<td></td>
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FGAN® - Future Prospects

The GaN wafer will improve the performance of the semiconductor elements for power conversion equipment (power devices), which will be key devices for realizing a low-carbon society, and also enhance the performance of wireless communication signal amplifiers (high-frequency devices), which support the coming 5G communication age.

**Application examples of power devices**

- Inverter for HEV/EV motor drive
- Power conditioner for photovoltaic power generation

**Application examples of high-frequency devices**

- Amplifier for cellular base station
- Amplifier for satellite communications

NGK is making efforts to realize next-generation power devices through joint research with Professor Hiroshi Amano, Nagoya University.

**Development roadmap**

- 6" GaN wafer (prototype)

  - For power device
    - Aim to place on the market in 2023

  - For high-frequency device
    - Aim to place on the market in 2021

  - 2" Wafer size
    - For ultra-high-brightness laser
    - For high-brightness laser

Defect density: 1/cm²